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PREPARED AT THE REQUEST OF

HON. HOWARD W. CANNON, *Chairman*
COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

DECEMBER 1978

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LETTER OF TRANSMITTAL

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
December 1, 1978.

DEAR COLLEAGUE: Many persons in the Government, the health sciences community, industry, academia, and the general public are interested in the possible effect of many forms of ionizing and nonionizing radiation on public health and safety. In recognition of that interest, the Committee on Commerce, Science, and Transportation conducted extensive public hearings in June 1977 to receive the viewpoint of all interested persons and organizations which would permit adequate evaluation of this important issue. The complete record of those hearings was printed and released as publication Serial No. 95–49.

On September 21, 1978, in executive session, committee members recognized that the extensiveness and complexity of this 1,224-page record required thorough analysis and supplemental study and accordingly directed the staff to publish the findings and recommendations of its study for subsequent review by the committee, as well as for the information and guidance of many persons with varying degrees of responsibility and interest in this matter.

This document has been prepared in accordance with that directive. Although this report has been neither approved, disapproved, or considered by the Committee on Commerce, Science, and Transportation, I believe it will prove important and useful to many recipients in their understanding of the effects of all forms of radiation on public health and safety, and in future actions taken with respect to these problems.

Sincerely,

HOWARD W. CANNON, *Chairman.*

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INTRODUCTION

In June 1977, the U.S. Senate Committee on Commerce, Science, and Transportation conducted 5 days of comprehensive oversight hearings on the subject of radiation health and safety. This document—prepared by the committee staff—provides a summary of the testimony, a report of findings and conclusions, and recommendations for future action.

The hearings were conducted for two principal reasons. First, the committee was concerned with the increasing number of radiation emitting sources to which the public is exposed. It has long been known that ionizing radiation can cause biological and genetic damage (e.g. production of leukemia or short-limbed dwarfism). Furthermore, experts have raised unanswered questions about the effects of nonionizing radiation. Since every person is exposed daily to some level of both ionizing and nonionizing radiation from manmade and natural sources, the Government has an obligation to determine what potential health hazards may exist and to provide safeguards to minimize their effect. Second, the committee played a major role in enacting the Radiation Control for Health and Safety Act of 1968. As a consequence, the committee was interested in determining how the act has been implemented. In addition, under the reorganization of Senate committees, the Committee on Commerce, Science, and Transportation has comprehensive oversight jurisdiction over policy matters relating to science, engineering and technology research and development.

The committee planned a comprehensive review of health and safety concerns related to ionizing and nonionizing radiation. In its preparatory work, the committee solicited data from 32 Federal agencies relative to their radiation research and regulatory efforts. It also requested the opinions of experts from the private sector on the adequacy of present Federal efforts in this area. A careful examination of data submitted prior to the hearing indicated the likelihood of confusion resulting from voids in and duplication of effort at the Federal level in both research and regulation. Therefore, the committee was interested in learning what might be done to coordinate or clarify those responsibilities to protect the public interest more effectively. In addition, the committee was aware of the public's concern over news reports, factual and speculative, concerning the harmful effects of radiation—for example, the controversy surrounding mammography, the microwave irradiation of the Moscow Embassy, and the Navy's proposed Project Seafarer.

The hearing developed a large body of scientific and technical opinion, which was divided on issues bearing directly on safety. Most of this information has been included in the committee's printed hearing record, serial No. 95–49. This present report presents findings and recommendations based upon study and evaluation of that record by the committee staff.

Testimony indicated that medical radiation accounts for more than 90 percent of all manmade ionizing radiation received by Americans, and that nearly one-third of all X-rays (i.e., 70 million to 90 million) may be unnecessary, contributing an estimated $2 billion each year to the Nation's medical bill. Many of these unnecessary X-rays appear to result from the lack of agreement among medical practitioners on criteria for determining when a specific X-ray procedure is needed and the lack of guidance available to the general public for balancing the risks and benefits of these exposures. In addition, testimony indicated that approximately 50 percent of the practicing radiologic technologists have had no formal training nor have they met any Federal, State, local, or professional certification requirements. Furthermore, the health hazards of persons (such as nuclear facility employees) subjected over long periods to low levels of ionizing radiation have not been adequately evaluated and that exposure limits for protection therefrom may not presently be adequate. This information indicates that the public is not adequately protected from the dangers of unnecessary exposure to ionizing radiation.

In the area of nonionizing radiation, witnesses testified that there are no mandatory limits for occupational exposure to nonionizing radiation and that the present voluntary system, in some cases, may not be adequate for employee safety. For example, a National Institute for Occupational Safety and Health (NIOSH) survey discovered that 75 percent of the equipment used for radio frequency (RF) sealing and heating purposes exceeded recommended exposure standards. Many of the affected employees do not realize that they are using RF radiation. It is therefore recommended that the Occupational Safety and Health Administration (OSHA) take prompt action to develop an adequate mandatory standard. Additionally, there are no standards to limit the exposure of the general population to microwaves and other nonionizing radiation produced by a growing number of industrial, military and consumer broadcast sources. An Environmental Protection Agency (EPA) response is clearly required.

To date, U.S. research on the biological effects of nonionizing electromagnetic radiation has identified no positive evidence of harmful effects to humans at the levels of exposure normally encountered by the general population. Nevertheless, because electromagnetic technology continues to pervade modern society, an accelerated program of research is required to determine what power levels, what exposure times, what frequencies and what modulation characteristics may be harmful.

Fragmentation of responsibility among the many Federal agencies involved in various aspects of radiation safety and control indicates the need for more effective direction and coordination.

The testimony revealed several areas where additional information was needed. Accordingly, the committee staff conducted supplemental studies of those issues. One, dealing with irradiation of the Moscow Embassy, will be the subject of a separate report. Three others dealing with (1) current X-ray diagnostic equipment available for reduction of dosage, (2) issues involved in reducing unnecessary diagnostic X-rays, and (3) current availability to the general public of equipment or services for checking microwave exposure levels in the home—particularly with reference to microwave ovens—are covered in appendices to this report. A fourth appendix provided by the Bureau of

Radiological Health, gives a detailed explanation of its estimate that 30 percent of all X-rays are unnecessary.

The following section of this report provides recommendations on actions to alleviate known radiation safety hazards and to provide the scientific base for resolving remaining unanswered questions of radiation safety.

RECOMMENDATIONS

Fundamental Research Needs

A coordinated program of federally sponsored research should be established which would include:

1. Experimental and epidemiological studies to determine the biological and/or behavioral effects of long-term exposure to low-levels of all forms of radiation to which significant segments of the U.S. population are subject. (I.B. p. 10; I.C. p. 11; II.A.3. p. 17; II.B. p. 18; III.A.2. p. 20; III.B.2. p. 23; III.C.1. p. 25; III.C.3. p. 28; and III.D. p. 29) [1]
2. Basic research into the physiological mechanisms by which biological and/or behavioral effects of exposure to nonionizing electromagnetic radiation may occur, with emphasis on developing principles for extrapolation of research findings from laboratory animals to humans. (I.C. p. 11; II.A.3. p. 17; III.A.2. p. 20; III.C.1. p. 25; III.C.3. p. 28; and III.D. p. 29)
3. Previously planned joint US/USSR experiments on the biological effects of long-term, low-level microwave exposure which have not yet begun. (The committee should review the overall mechanism for planning, conducting and managing joint studies of this type.) (III.C.3. p. 28)

Recommendations for the implementation of those actions which require multiagency participation will be found under the heading Jurisdictional Issues.

Medical Uses of Ionizing Radiation

An important step in eliminating unnecessary X-rays will be the establishment of criteria for determining whether a specific examination is or is not required. To this end the Bureau of Radiological Health (BRH), in conjunction with the American College of Radiology, the American Medical Association, the American Dental Association, as well as competent representatives of public and professional groups, should accelerate current efforts to develop and support adoption of criteria for deciding when X-rays are needed for a broad range of diagnostic applications. These criteria should also point toward elimination of certain routine uses of X-rays where no other evidence indicates the need, such as pre-employment physicals, hospital's pre-admission procedures, mammography for certain age groups and semi-annual dental exams. These criteria should consider the problems associated with the use of X-rays to guard against malpractice suits. Concurrent with these activities, the BRH should assist the public in understanding how to balance the risks and benefits of X-ray use. (II.A.2.b. p. 13)

[1] Numbers in parentheses identify the location in the Principal Findings of information which prompted these recommendations.

One of the principal means for guarding against excessive exposure to X-rays is to assure the competence of medical and dental X-ray operators. In this connection the Bureau of Radiological Health, working with professional organizations such as the American Society of Radiologic Technologists, the Conference of Radiation Control Program Directors, and the American College of Radiology, should develop and encourage the adoption by the States of standards for the accreditation of X-ray machine operators and institutions conducting educational programs in radiologic services.[2] (II.A.2.c. p. 14)

To further assist in improving the medical applications of radiation:

1. The Department of Health, Education, and Welfare (DHEW) should increase and stabilize funding for needed expansion and continuity of current BRH cooperative programs with State health departments involving inspection of newly installed X-ray equipment and quality assurance programs for existing X-ray systems; (II.A.2.d. p. 15)

2. The BRH, working with insurers, health maintenance groups, professional organizations, and consumer groups active in public health issues, should promote broader use of its wallet-size individual X-ray and vaccination record; and (II.A.2.b. p. 13)

3. DHEW should conduct a study of the extent to which the principal users of medical X-ray systems are adopting or converting to equipment which can provide adequate diagnostic information with minimum radiation exposure to the subjects at reasonable costs. DHEW should report its findings to the Congress with recommendations, if necessary, for appropriate regulatory or legislative action. (II.A.2.d. p. 15)

Occupational Exposure to Ionizing Radiation

A coordinated Federal program should be established to determine the extent to which occupational exposure to low-levels of nuclear radiation may be a causal factor in subsequent health problems. This program should provide a basis to assess, and if necessary, to alter present standards for occupational exposure to ionizing radiation. (II.B. p. 18)

A coordinated Federal program should be estabilshed to identify, assess and, if necessary, regulate the exposure hazard from any radioactive materials (such as those produced by cyclotrons), or radiation emitting equipment which are not within the jurisdicton of the NRC or other Federal agencies. (IV.A. p. 30)

Congressional committees with oversight or legislative jurisdiction over the Occupational Safety and Health Administration should examine the adequacy of funding and priority assigned by OSHA for protecting workers from excessive ionizing radiation exposure. (II.B. p. 18)

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[2] Voluntary and mandatory approaches for implementation of such standards are contained in Part III of S. 3290, the Consumer Patient Radiation Health and Safety Act of 1978, and in S. 1695, the Radiation Health and Safety Act of 1977.

Exposure to Nonionizing Radiation

The OSHA, in cooperation with other responsible organizations and Federal agencies, should give priority to a review of the adequacy of its present voluntary standard for occupational exposure to nonionizing radiation. After making any necessary changes, OSHA should promulgate a mandatory standard. While conducting this review, OSHA should consider converting the present voluntary standard to a mandatory standard on an interim basis. (II.B.2. p. 23)

The Office of Technology Assessment (OTA) should conduct a study (1) to project the impact of emerging technologies on the levels of nonionizing electromagnetic radiation in the environment and (2) to assess the economic and functional impact of imposing an upper limit on such radiation. (The committee should request authorization of such a study by the Technology Assessment Board of the OTA). (III.A.2. p. 20)

The National Bureau of Standards (NBS) should intensify its efforts to provide the physical measurement standards, calibration services, and standardized measurement techniques necessary for research and regulatory activities relating to nonionizing radiation. (III.C.1. p. 25) Additionally, NBS in conjunction with the Conference of Radiation Control Program Directors, should prepare for the committee on Commerce, Science, and Transportation a review of the need for an intermediate level of calibration services, such as regional facilities to better couple NBS laboratories with State and industrial needs. (IV.A. p. 30)

After completion of its current national survey of ambient nonionizing radiation, EPA should determine whether a mandatory upper limit is needed. (III.A.2. p. 20)

OSHA, in cooperation with NIOSH, should assess the need for standards to control occupational exposure to ultrasound, and BRH should assess the need for standards to control medical uses of ultrasound. (III.D. p. 29)

Jurisdictional Issues

Several committees of the Senate and House have been examining the adequacy of organization and coordination of Federal programs in radiation protection and research. Given the complexity of existing organizational problems, it will be difficult to develop a solution that is totally satisfactory to all parties. Information developed in these hearings and in subsequent staff investigations, suggests that three actions are fundamental to correct the present organizational deficiencies:

1. The President should resolve at the earliest practical date the jurisdictional ambiguities in Federal agency responsibilities which prevent a coordinated approach to radiation research and regulation. This effort should be coordinated with those committees of the Congress which have legislative and oversight jurisdiction over these activities. (IV.A. p. 30 and IV.C. p. 37)

2. The President should establish an executive-level position within the Executive Office of the President with the sole responsibility of

providing sustained coordination of the multiagency radiation research and regulatory effort. While we do not intend to indicate the detailed support structure for this position, it is essential that it have the following capabilites:

Authority to decide among competing jurisdictional and regulatory activities of the various agencies;

Authority to involve representatives of affected agencies on a regular basis;

Direct access to the President in implementing decisions regarding agency roles and responsibilities; and

Adequate staff to carry out these responsibilities.

This coordinating mechanism should provide for Presidential-level review of agency performance and direction of agency responsibilities, priorities, and funding levels. It is essential that the present situation of jurisdictional ambiguity and overlapping not be permitted to recur once the existing problems have been rectified. (IV.B. p. 37 and IV.C. p. 37)

3. The coordinating mechanism established above should make extensive use of existing advisory bodies—specifically the National Academy of Sciences/National Research Council's Committee on Biological Effects of Ionizing Radiation and the Department of Commerce's Electromagnetic Radiation Management Advisory Council. These panels can assist in evaluating present research activities and in establishing priorities among those areas of research which need additional attention. In addition, medical and industrial users of radiation, electronic product manufacturers, the nuclear industry, employee representatives, the radiation research community, and members of the affected public should be consulted in reviewing the radiation protection performance of Federal agencies, and in assigning agency responsibilities and priorities. (IV.C. p. 37)

PRINCIPAL FINDINGS

This section of the report includes the principal findings derived from study and analysis of the hearing record, particularly the testimony of witnesses who appeared before the committee. A number of these findings deal with issues considered sufficiently vital to the overall subject of radiation health and safety to warrant recommendations for further action or investigation by appropriate agencies of the Government. Other findings identify issues or problems raised by witnesses for which recommendations were not made due to insufficient evidence in the hearing record. Some additional information submitted by the witnesses has also been included to assist readers in their overall understanding of the issues and recommendations.

I. GENERAL CHARACTERISTICS OF RADIATION

A. Classes and Uses of Radiation

Two different classes of radiation were discussed during the hearings—ionizing and nonionizing. Ionizing radiation includes X-rays, as well as radioactive decay products, such as neutrons, alpha and beta particles, and gamma rays. Nonionizing electromagnetic radiation includes radio, television and microwave transmissions, visible light, ultraviolet, infrared, and the electromagnetic fields from electric power transmission lines.

Some properties of ionizing and nonionizing radiation are essential to human existence; others have contributed to the present quality of life. Photosynthesis in plants, radiant heat, television, radio, radar, microwave diathermy treatment for arthritis and sprains, photography, automatic garage door openers, air and marine navigation systems, citizens-band radios, and driver-aid call boxes along our highways all depend (Osepchuk, p. 204 and Thaler, p. 682)[1] upon nonionizing electromagnetic radiation. Similarly, ionizing radiation is an integral part of nuclear electric power production and (Harris, p. 590) is also used for nondestructive testing in industry, as well as for vital medical diagnostic and therapeutic procedures. However, as with many products of modern technology, these different kinds of radiation, if carelessly or improperly used, can have undesirable or dangerous effects. Moreover, the average person's exposure to both ionizing and nonionizing radiation continues to increase because more radiation-emitting products, as well as more diagnostic and therapeutic techniques, are now available (Gardner, p. 19; Rall, p. 670; Thaler, p. 686). Unfortunately, one may experience undesirable or even harmful exposure to radiation without any sensory awareness at the time.

[1] Page numbers appearing in parentheses indicate the location in the printed Hearing Record (Serial No. 95–49, of the Committee on Commerce, Science, and Transportation) of testimony relating to these findings.

B. Biological Effects of Ionizing Radiation

The testimony of Dr. Stefan Schiff (p. 4) and Dr. William Thaler (p. 682) indicated that ionizing radiation interacts with biological systems in various ways. Depending upon their frequency (or energy), electromagnetic waves (X-rays and gamma rays) can be totally or partially absorbed by the human body. The interactions of the particles produced by radioactive decay processes with biological systems will depend on the kind of particle involved (neutrons, alpha and beta particles, neutrinos, et cetera), the location of the particle's source relative to the subject, and the particle's energy.

In speaking about nonparticulate ionizing radiation, namely X-rays and gamma rays, Dr. Schiff (p. 10) explained:

> The sequence of events initiated by ionizing radiation is as follows. The energy of the radiation is dissipated by the production of ionization, that is, by knocking electrons out of atoms. These electrons in turn may ionize other atoms; approximately 32.5 electron volts of energy are required to produce one ionization. One X- or Gamma-ray therefore may ionize many atoms in its path through tissue. As the energy of the radiation is dissipated, the number of ionizations per unit of path increases, so that the greatest concentration of ionizations occurs at the end of the path. The ionization of atoms, in turn, produces physical and chemical changes, such as bond breakage in molecules and other structural alterations. These physical and chemical changes subsequently lead to the production of biological effects. . . . Even a small alteration in a single gene may result in the production of a mutation. Such a mutation may be inconsequential; on the other hand, it may lead to the production of major abnormalities, such as malignancies. A host of human diseases which are traceable to mutations have been identified in recent years. All of these can be induced by radiation, although they may also be the result of spontaneous errors or chemical effects.

Dr. Schiff (p. 5) noted that mutations in reproductive cells are of particular concern because defects in these cells can be transmitted to future generations.

Mr. Lee Gossick of the Nuclear Regulatory Commission (NRC) (p. 438) pointed out that scientists have been collecting data relating to ionizing radiation's effects on humans and animals for 50 years. While the biological effects of a large dose of ionizing radiation received during a short time are well known, there is less agreement regarding the effects of long-term, low-level exposure comparable to the measured radiation background level. Mr. Gossick believes that more research is needed to resolve these uncertainties, especially in view of recent concerns over the safety of persons who live near nuclear facilities or are exposed to ionizing radiation in the workplace. In addition, he noted that there are new radioisotopes whose biological effects are not well understood.

Testimony indicated that precise quantitative information is not available regarding the biological effects of exposure to low levels of ionizing radiation (e.g., Schiff, p. 5 and Liverman, p. 505). Lacking this information it is prudent to assume (Rowe, p. 76; Liverman, p. 505) that there does not exist a threshold of danger, i.e., a specific level of exposure below which there are no ill effects. In fact (Liverman, p. 505), regulations of the NRC and the EPA are based upon the assumption that it is possible, by using simple proportions, to predict the damage caused by low exposure levels on the basis of the known effects of high exposure levels. This "linear nonthreshold extrapolation tech-

nique" suggests that the number of cancers caused by a dose of 0.5 rads [2] will be 1/100 the number of cancers caused by a dose of 50 rads. There is, however, considerable disagreement over the reliability of this technique. Some experts (e.g., Bross, p. 171) believe it seriously underestimates the health effects of low-level exposures; other experts (e.g., Morgan, p. 242) believe it overestimates such effects.

Even if these questions were resolved, two additional questions would remain: (1) what levels of risk are acceptable; and (2) what administrative procedures should be used to keep exposure below these acceptable levels?

C. Biological Effects of Nonionizing Radiation

Dr. Schiff (p. 11) also commented on the biological effects of nonionizing radiation—especially microwaves. He explained:

> The characteristics of microwaves and other nonionizing radiation differ greatly from those of ionizing radiation. Microwaves have a very low energy (fraction of one electronvolt) and therefore cannot produce ionizations.
>
> The amount of microwave energy absorbed depends upon the electrical properties of the tissues (dielectric constants and conductivity); in general, tissues with high water content will absorb relatively greater amounts of microwave energy. The greater the frequency of the microwaves, the less deeply they penetrate: at 10^4 MHz and higher frequencies, they do not penetrate beyond the skin; at frquencies below 150 MHz they pass through the body with very little interaction.
>
> The means whereby microwaves produce damage is somewhat controversial at present. Microwaves of power densities of 100 mW/cm^2 or greater are generally conceded to produce thermal effects with prolonged exposure leading to hyperthermia and death. Microwaves in the 10 to 100 mW/cm^2 range are generally presumed to cause thermal damage, but there is some question as to whether or not the effects are entirely due to heating. Some researchers feel that differential heating of tissue may lead to the production of "hot spots", that is, small areas which absorb more heat than the surrounding tissues, so that localized thermal damage would occur. A number of effects have been reported at power densities of 10 mW/cm^2 or lower, but a satisfactory mechanism to explain how the damage might be produced at such levels has not yet been determined. A variety of physical and chemical changes have been proposed, but supportive evidence is lacking.
>
> Most of the data pertaining to the biological effects of microwaves come from experimental studies involving rabbits, mice, dogs and other mammals. Human data are derived primarily from acute accidental exposures to microwave-generating equipment, and from retrospective studies of occupationally employed personnel.

A more complete discussion of observed biological effects of nonionizing radiation is given in section III.C below.

As pointed out by Dr. James Liverman (p. 505) and Dr. Roger Mattson (p. 438), it is also important to bear in mind that for very low levels of exposure to any biological insult—ionizing or nonionizing radiation, carcinogens, noise, cigarettes, et cetera—it is often difficult to separate the effects of one specific pollutant from the normal occurrence of ill health in the population under investigation.

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[2] A rad is a unit used to measure the amount of energy actually absorbed and is to be distinguished from the level or intensity of exposure measured in roentgens. A millirad is 1/1000 of a rad.

In view of the many questions which remain to be answered, it is recommended that a coordinated program [3] of federally sponsored research should be established which would include:

1. Experimental and epidemiological studies to determine the biological and/or behavioral effects of long-term exposure to low levels of all forms of radiation to which significant segments of the U.S. population are subjected.

2. Basic research into the physiological mechanisms by which biological and/or behavioral effects of exposure to nonionizing electromagnetic radiation may occur, with emphasis on developing principles for extrapolation of research findings from laboratory animals to humans.

II. IONIZING RADIATION

A. Exposure of the General Public

1. BACKGROUND RADIATION

Background radiation from cosmic rays or naturally occurring radioactivity in rocks and soil is a major source of human exposure to ionizing radiation. The exact level of exposure varies throughout the Nation. According to EPA's Report No. 520/1–77–009, Radiological Quality of the Environment in the United States, 1977, the average citizen in Louisiana, for example, receives about 75 millirems [4] per year from cosmic and terrestrial sources, whereas in Colorado the average level rises to about 225 millirems per year because of differences in altitude and mineral deposits.

2. MEDICAL USES OF IONIZING RADIATION

a. Extent of exposure

Medical radiation—diagnostic and therapeutic—accounts (Morgan, p. 232) for more than 90 percent of all manmade ionizing radiation received by Americans. According to HEW Publication (FDA) 77–8032, "A Look at FDA's Program to Protect the American Consumer from Radiation," the annual number of X-rays administered to Americans has increased by about 4 percent each year since 1964. The total (Gardner, p. 16) was expected to reach 270 million in 1977. Dr. Russell Morgan (p. 242) estimated that as many as three of every five Americans receive an X-ray examination each year. Dr. Morgan further estimated that Americans absorb an average dose of 60–100 millirads of radiation per year from medical sources, compared to an average dose of 80 millirads per year from natural sources. Of course, these average levels can be substantially exceeded for many individuals.

Witnesses (e.g., Kushner, p. 122, Hardin, p. 702) agreed that patient exposure to ionizing radiation should be reduced to the minimum level

[3] Section IV.C. of the findings contains recommendations for the implementation of those actions which require multiagency participation.

[4] A rem is a special unit used to measure the dose of ionizing radiation. One rem equals the amount of ionizing radiation of any type which produces the same damage to humans as one roentgen of approximately 200 kilovolts X-radiation. A millirem is 1/1000 of a rem. A roentgen is the international unit of X- and gamma radiation exposure. One roentgen is the amount of X- or gamma radiation necessary to produce ionization equal to one electrostatic unit of charge in one cubic centimeter of standard air.

that will provide appropriate diagnostic information or needed therapy. This goal can be accomplished by (a) eliminating unnecessary X-ray examinations; (b) using high performance X-ray systems,[5] and adjusting existing equipment in order to obtain the lowest possible radiation exposure which provides an interpretive image; (c) using well-trained technologists who can operate the equipment safely, and who understand the biological effects of radiation; and (d) adopting quality assurance programs to improve the safety of the entire X-ray system.

b. Medical practice

The Bureau of Radiological Health (BRH, within FDA) has identified the ordering of unnecessary X-ray examination as the greatest contribution to patient exposure and health care costs (Gardner, p. 35; also Schiff, p. 8). They have estimated (Villforth, p. 28) that about one-third of all X-ray procedures (i.e., about 70 million to 90 million annually) are not necessary (i.e., they have no effect on patient care).[6] These unnecessary X-rays contribute about $2 billion each year (Gardner, p. 35) to the Nation's medical bill, as well as unnecessary radiation exposure for many individuals. Most of these X-rays are paid for by third-party insurers (Bross, p. 172). An AMA study was cited (Bross, p. 172) indicating that three out of four American physicians occasionally order X-rays to defend themselves against potential malpractice suits. Other reasons for unnecessary X-rays (Bross, 172) include out-of-date medical procedures, requirements for preemployment physicals or hospital admissions, inaccessibility of prior medical records, and operating errors by technicians which require exposures to be repeated. Mrs. Rose Kushner (p. 114) indicated that there is no controversy regarding the use of diagnostic mammography when possible symptoms of the disease are observed. However, since ionizing radiation can cause cancer, and since its effects are cumulative, she believes (p. 115) that the risks of routine X-ray mammography screening to detect early signs of breast cancer outweigh the benefits among large populations of women in specific age brackets.[7]

The medical community has been urged (e.g., Hardin, p. 708) to establish more effective guidelines to assist physicians in determining when X-rays are required. Some progress is being made. For example, under an FDA contract, radiologists at the University of Washington (Villforth, p. 28) developed criteria which resulted in a 40 percent reduction in the number of skull X-rays administered in one hospital's emergency room. A notice, published on p. 4377 of the Federal Register on February 1, 1978, describes radiation protection guidelines for the use of diagnostic X-rays that were jointly developed by the EPA and FDA. However, these guidelines apply only to Federal facilities and are not mandatory.

In response to these observations, it is recommended that the BRH, in conjunction with the American College of Radiology, the American

[5] See appendix A for a more detailed discussion of recent advances in medical X-ray technology.

[6] See detailed report by BRH, included as appendix B.

[7] Recognition of this fact (Kushner, p. 119) led the National Cancer Institute in May of 1977 to issue new guidelines which restrict screening by mammography of women under age 50 to those who have had breast cancer themselves or whose close relatives have had the disease. These guidelines are binding at the 27 Breast Cancer Detection Centers but not for the 5,000 other machines used for mammography (Kushner, pp. 116 and 119).

Medical Association, the American Dental Association, as well as competent representatives of the public and professional groups, accelerate current efforts to develop and support adoption of criteria for deciding when X-rays are needed for a broad range of diagnostic applications. These criteria should also point toward elimination of certain routine uses of X-rays where no other evidence indicates the need, such as preemployment physicals, hospital preadmission procedures, mammography for certain age groups, and semiannual dental exams. These criteria should consider the problems associated with the use of X-rays to guard against malpractice suits. Concurrent with these activities, the BRH should assist the public in understanding how to balance the risks and benefits of X-ray use.

Establishment of a national system to record individual X-ray exposures is another possible way to protect against excessive radiation (see appendix C). Such records could show the number and kind of X-ray examinations to which a person has been exposed, but not the amount of radiation absorbed (because this cannot be measured easily). The economic and administrative problems associated with maintaining such a comprehensive records system are also formidable. Any such system would need safeguards to protect the privacy of individual medical records.

On a smaller scale the BRH (Villforth, p. 27) is now testing a wallet-size patient record card which lists the date and type of examination, referring physician, and address where X-rays are kept. BRH should be commended for this development and encouraged to work with insurers, health maintenance groups, professional organizations, and consumer groups active in public health issues in order to promote broader use of this wallet-size individual X-ray and vaccination record.

c. Operator credentials

A high level of competence must be maintained among radiologic technologists. An untrained or careless operator of medical or dental radiologic equipment can damage a patient's health, as well as his or her own health. The president of the American Society of Radiologic Technologists, Mr. Richard Bauer (p. 764) noted that although there are 130,000 to 150,000 operators of radiologic equipment in the United States, only about one-half have voluntarily met the educational standards and passed examinations prescribed by the American Society of Radiologic Technologists. The remaining 50 percent have no officially recognized qualifications. Since the patient is rarely in a position to judge either the qualifications of the X-ray operator or the quality of the examination, it is important that operators have the knowledge and training that will insure safe procedures. According to Mr. Bauer (p. 764) a minimum accreditation program for health manpower did exist prior to 1971. At that time, HEW requested a moratorium in this program in order to study accreditation. However, Mr. Bauer reports that HEW has made no discernible progress in developing operator standards since 1971.

At the time of the committee's hearings (Hardin, p. 703), New York, New Jersey, California and Puerto Rico required training and certification of X-ray technologists.[8] Ten additional States have passed

[8] Two additional States (Kentucky and Arizona) have been added since the hearings, Florida and West Virginia are expected to add similar requirements early in 1979.

enabling legislation that will permit licensing to be required at some future date. Numerous witnesses (e.g., Kushner, p. 121; Hardin, p. 707; Bauer, p. 764) agreed that Federal action is needed to insure competence among X-ray technologists. The Conference of Radiation Control Program Directors (Hardin, p. 707) believes that licensing should be handled by the States in accordance with guidelines established by the Federal Government. In fact, in 1974 the conference (Hardin, p. 734) adopted a resolution urging the Congress and State legislatures to implement such a program.

At its 1977 Washington convention, the American Society of Radiologic Technologists (Bauer, p. 765) gave unanimous support to the proposed Radiation Health and Safety Act of 1977, introduced by Senator Jennings Randolph. This bill would authorize States to administer a program for accrediting educational institutions and licensing radiologic technologists on the basis of federally developed criteria and minimum standards.[9]

In view of the consensus on this issue, it is recommended that BRH, working with professional organizations such as the American Society of Radiologic Technologists, the Conference of Radiation Control Program Directors, and the American College of Radiology, develop and encourage the adoption by the States of standards for the accreditation of X-ray machine operators and of institutions conducting educational programs in radiologic services.

d. Performance of medical X-ray equipment

The Radiation Control for Health and Safety Act of 1968 (Public Law 90–602) authorizes the Secretary of Health, Education, and Welfare to establish performance standards for radiation-emitting electronic products. Enforcement of these standards is a responsibility shared by the Bureau of Radiological Health and the States (Villforth, p. 66). For example, in order to assure compliance with its standards for newly installed diagnostic X-ray equipment (about 15,000 new systems each year, Gardner, p. 15) the BRH (Gardner, p. 17) has contracted with 18 [10] States to make onsite inspections. Thirty percent of the machines tested in these States (Villforth, p. 21) have failed to meet prescribed performance standards. In these 18 States, it is usually feasible to make prompt onsite corrections. Furthermore, information concerning design or manufacturing defects can be forwarded to manufacturers and regulatory personnel for further product improvement. BRH staff members indicated that there are approximately 10 regional radiation health representatives available to monitor new X-ray installations in the remaining 32 States not under contract to BRH. They conduct approximately 1,000 compliance surveys each year (Gardner, p. 67). BRH testified (Villforth, p. 22) that budget restraints within FDA prevented any substantial expansion of the program at that time.

Senator Ford (pp. 22 and 24) indicated that less than $1 million would be needed to extend BRH contracts to all of the States capable of participating. However, Mr. Hardin, who represented the Conference of Radiation Control Program Directors, indicated (p. 710) that some of the States are unwilling to participate because they fear

[9] Model legislation which provides for certification of persons who apply or supervise the application of ionizing radiation to humans was developed by BRH as early as 1970.
[10] Four additional States have been added since the hearing.

that as soon as people have been hired, equipment purchased, and programs started, the funds would be withdrawn. He had already noted (p. 705) the lack of Federal grants for training State personnel.

BRH has initiated three voluntary programs to assess and improve the use and performance of X-ray equipment. These programs are: NEXT—Nationwide Evaluation of X-ray Trends; BENT—Breast Exposure: Nationwide Trends; and DENT—Dental Exposure Normalization Technique.

According to Dr. Gardner (p. 17) 39 States and 7 Federal agencies are participating in BRH's NEXT program to measure the effectiveness of State and Federal regulatory activities to reduce patient's X-ray exposure. Mrs. Kushner (p. 117) reported that spot checks of medical facilities (including hospitals, private radiologists' offices and clinics) by BRH under the BENT program revealed that some mammography equipment was emitting as much as 47 roentgens per exposure, about 10 times higher than accepted levels. BRH's DENT program is being used (Gardner, p. 18) to monitor the operation of about 75,000 dental X-ray machines, constituting about two-thirds of those in the United States, with the States reporting an average 40 percent reduction in patient exposure to X-radiation.

Since BRH quality assurance programs (NEXT, BENT, and DENT) apply to all X-ray machines, regardless of the date of manufacture, they can be particularly effective in identifying X-ray systems which require either the attention of State officials or the agency's own regional radiation health representatives.

In 1975, the States spent a total of $11 million on inspection activities involving 25,000 dental and 27,000 medical X-ray machines. Although radiation protection programs exist in every State, witnesses (e.g., Kushner, p. 136; Taylor, p. 139; Morgan, p. 248) noted wide variations in the ability of States to control the quality and performance of equipment in service. Since BRH lacks statutory authority (1) to inspect X-ray equipment manufactured prior to 1974,[11] (2) to regulate the use of any X-ray equipment, or (3) to require participation of the States in any of the monitoring programs noted above, its overall safety-monitoring capability is limited. Mrs. Kushner (p. 118) characterized the situation by observing, "Our watchdog has no teeth." Nevertheless, the Conference on Radiation Control Program Directors in its testimony (Hardin, p. 708) implied there was no need to expand FDA authority to include checking previously installed X-ray machines. Nor has the BRH sought any extension of this authority.

This information suggests that DHEW should increase and stabilize funding for the needed expansion and continuity of current BRH cooperative programs with State health departments involving the inspection of newly installed X-ray equipment and quality assurance programs for existing X-ray systems. Looking to the future, DHEW should conduct a study of the extent to which principal users of medical X-ray systems are adopting or converting to equipment which can provide adequate diagnostic information with minimum radiation exposure to the subjects. DHEW should report its findings to the Congress with recommendations, if necessary, for appropriate regulatory

[11] Some additional information on BRH authority to control machines installed between 1968 and 1974 will be found on pp. 66 and 67 of the hearing record.

or legislative action. If these steps can be coupled (a) with adoption by the States of a system for accrediting both X-ray machine operators and their training facilities and (b) with vigorous pursuit of present BRH educational programs for radiologists and radiologic technologists, then steady and measurable progress should be expected.

3. RADIOACTIVITY FROM COAL

Whereas perceived radiation hazards associated with nuclear power generation are well publicized, there is little awareness that radiation can also be released by the burning of certain coals (mainly soft coals from Western States—Rowe, p. 87). A report prepared for transmittal to the Secretary of HEW on December 23, 1977, by the Committee on Health and Environmental Effects of Increased Coal Utilization [12] concluded, "Radiation from increased coal combustion does not represent a significant public health problem." This conclusion was based upon the assumption that a 1,000 MWe coal-fired powerplant would contribute a maximal annual whole body dose commitment to the most exposed individuals of only 0.04 to 0.35 mrem/yr. However, EPA's publication Radiological Quality of the Environment in the United States, 1977 (EPA 520/1–77–009) estimates that individual dose rates from such a plant could range from 38 to 380 mrem/yr. None of the Federal regulatory agencies (Gossick, p. 441) are presently regulating radioactive emissions from coal-fired generating plants, nor are any of the States monitoring such emissions (Hardin, p. 707). In view of these uncertainties and further questions about the tendency of certain radioactive particles to concentrate in foodstuffs, additional research is justified to determine whether a potential radiation hazard exists.

4. OTHER SOURCES OF PUBLIC EXPOSURE

According to Dr. James Liverman (p. 500) 19,000 homes, schools, and other buildings in Grand Junction, Colo. have been examined by the Department of Energy (DOE) to determine what action must be taken to correct any radiation hazards stemming from the use of uranium mill tailings for landfill. It appears that soil beneath about 600–700 structures will have to be removed. Twenty-two other Western sites must be surveyed to determine whether similar problems exist.

Dr. Liverman (p. 501) also estimated that by 1980, DOE will have about 1,000 different facilities which have been contaminated with nuclear radiation. Due to a Presidential decision in 1964 to reduce production levels of nuclear materials, about one-half of these facilities are surplus to current needs and will have to be disassembled and/or decontaminated. DOE staff members have indicated that 30 to 50 of these could be classified as major facilities (i.e., large buildings, laboratories, nuclear reactors, or chemical processing plants); the remainder consist of support facilities such as tank farms, inactive burial grounds, trenches or areas that have been contaminated by spills. The total cleanup bill was estimated by DOE (Liverman, p. 501) to be $3 to $5 billion.

[12] This committee was established in October 1977 by President Carter to review the potential impacts of his energy plan which placed a strong emphasis on the increased use of coal.

B. Occupational Exposure

Dr. Elliott Harris (p. 590) told the committee that the major sources of worker exposure to ionizing radiation include X-ray devices for industrial radiography and nondestructive testing,[13] accelerators for research and radionuclides such as radium and radon which are also used for inspection purposes. In regard to worker protection, Mr. Lee Gossick (p. 435) explained that since any excess exposure to ionizing radiation should be discouraged, the Code of Federal Regulations has, since 1971, required that worker exposure to ionizing radiation be kept not only within the mandatory limits, but "as low as practicable" or "as low as reasonably achievable."

The adequacy of present standards limiting worker exposure to ionizing radiation has come under serious question in the months following these hearings—principally as a result of reports[14] which suggest a higher proportion of cancer deaths among nuclear workers than for the general public. These standards have not been reviewed during the 6 years that OSHA has existed (Wrenn, p. 569). OSHA has attributed this inaction to the more urgent priority of effort on controlling health hazards such as those associated with vinyl chloride, asbestos, arsenic, and benzene (Wrenn, p. 570). In the meantime, OSHA has established an Office of Physical Agents Standards which, among other things, is to review existing standards for ionizing and nonionizing radiation (Wrenn, p. 575). However, such a review did not appear on its list of priorities through July 1978 (Wrenn, p. 575). During fiscal year 1976, OSHA (Wrenn, p. 574) conducted only 28 inspections for ionizing radiation health hazards. Furthermore, OSHA has acted on only a small fraction of the criteria documents developed by NIOSH, some of which deal with occupational exposure to radiation (Harris, p. 588).

We believe that there is a need for congressional committees with oversight or legislative jurisdiction over OSHA to examine the adequacy of funding and priority assigned by OSHA for protecting workers from excessive ionizing radiation exposure.

Senator Stevenson (p. 571) reported some employee concerns regarding X-ray baggage inspection units at airports. An investigation by committee staff members supported the testimony of witnesses (Wrenn, p. 571; Harris, pp. 584 and 600) that these units present no serious employee or public exposure problems. Rules of the Federal Aviation Administration (FAA) and BRH (Gardner, p. 65) mandate that this equipment be inspected every 6 months and that employees wear dosimeters (film badges) at all times. However, greater care could probably be exercised over the control of dosimeters.

Mr. Charles Hardin (p. 703) indicated a considerable degree of State activity relating to occupational exposure to ionizing radiation. Thus, 43 States, Puerto Rico, and the District of Columbia have regulatory programs in industrial X-ray control, and 25 States have signed agreements with the NRC to assume regulatory authority over certain classes of nuclear material, specifically, source byproduct, and small quantities of special nuclear material.

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[13] Nondestructive testing is a term commonly applied to inspection and quality control techniques such as X-ray examination of pipe welds, which do not harm the device being tested.

[14] Washington Post, Feb. 18, 1978 and Boston Sunday Globe, Feb. 18, 1978.

Several studies are underway to monitor the health effects of occupational exposure to ionizing radiation. For example, NIOSH (Harris, p. 584) is presently monitoring the health of a large group of uranium miners who had been exposed to radioactive gases, while DOE (Liverman, p. 497) is funding projects to study (a) radiation's effects on 109,000 survivors of the 1945 atomic bomb blasts, (b) 10,000 people who received injections of radioactive thorium or radium, and (c) workers exposed to radiation in any form other than plutonium or transuranium elements over the total life of the Atomic Energy-Manhattan Engineer District. The results of such studies are of great interest to regulatory and advisory bodies responsible for establishing or enforcing standards of occupational exposure.

A coordinated and well managed program of federally sponsored research is needed to determine the extent to which occupational exposure to low levels of nuclear radiation may be a causal factor in subsequent health problems, thus providing a basis to assess, and if necessary, to alter present standards for occupational exposure to ionizing radiation.[15]

III. NONIONIZING RADIATION

A. Exposure of the General Public

1. EXTENT OF EXPOSURE

There has been a rapid growth in the use and deployment of electronic equipment and systems for military, industrial, and consumer applications which generate and emit electromagnetic radiation between infrared and extremely low frequency (ELF). Sources of electromagnetic radiation [16] include the 9 million transmitters authorized by the Federal Communications Commission as of 1977 (including 4,500 AM and 4,000 FM radio stations and 1,000 TV stations), point-to-point microwave communications relay towers, satellite ground stations, the 40,000 circuit miles of overhead extra-high voltage (345 to 765 kV) AC electrical transmission lines, and the 30 million citizen's band radios estimated to be now in use. Additional sources include microwave ovens (an estimated 8 million in use), automobile and other combustion engine ignitions, electric motors, and intrusion protecting systems (devices which use electronic systems such as microwaves, lasers, or ultrasound to detect and warn of the presence of unauthorized individuals).

The Department of Defense (DOD) (Austin, p. 311) is the Nation's largest user of nonionizing electromagnetic radiation devices, including a wide variety of reconnaissance, surveillance, and communications systems in air, sea, and ground operations. The U.S. Army alone has nearly 350,000 devices (Larsen, p. 349) which transmit electromagnetic radiation in the frequency range from 3 kHz to 40 GHz.

At the present time, EPA surveys (Galpin, p. 85) indicate that the average nationwide intensity of nonionizing radiation to which the public is exposed is approximately 0.01 to 0.02 microwatts/cm^2. (One

[15] See, also, the discussion relating to naturally-occurring and accelerator-produced radioactive materials in section IV.A. of the findings.

[16] Testimony of John W. Lyons, National Bureau of Standards, before the Committee on Commerce, Science, and Transportation's Subcommittee on Communications, June 14, 1978.

microwatt/cm² is 10,000 times less than the recommended upper limit for occupational exposure.)[17] However, individual exposures may be considerably higher depending upon one's occupation or location near radiation-emitting devices. Dr. William J. Thaler, Acting Director of the Office of Telecommunications Policy, emphasized (p. 683), ". . . the research program to date has identified no positive evidence of harmful effects to man at the levels of exposure normally encountered by the general population. No crisis has been found to exist. No cause for public alarm has been identified. We must, however, be absolutely certain that nothing has been overlooked, and we recommend continued and accelerated pursuit of the necessary research." Similar sentiments were expressed by Dr. Osepchuk (p. 204), Dr. Pollack (p. 282), and Dr. Setlow (p. 753).

2. LACK OF ENVIRONMENTAL EXPOSURE LIMITS

Although 21 States (Hardin, p. 703) have specific statutes relating to the control of nonionizing radiation sources, the Federal Government (Rowe, p. 93) has not established exposure limits applicable to the general public for nonionizing radiation from either single point or multiple sources.[18] One reason is that the medical and related scientific community has been unable to establish conclusively the quantitative parameters which define the possible health hazards of nonionizing radiation.[19] For example, scientific evidence is lacking in regard to: (a) whether there is a nonthermal mechanism by which nonionizing radiation might produce biological effects (Schiff, p. 6; Tyler, p. 358); (b) whether there exists a threshold level below which no damage could occur, regardless of the duration of the exposure (Schiff, p. 7; Tyler, p. 358); and (c) whether there are specific frequencies or modulation characteristics which have high potential for hazard (Osepchuk, p. 206; Austin, p. 340; Tyler, p. 358; and Thaler, p. 683).

There are broad differences of opinion on these and other questions which are fundamental to the consideration of exposure limits for nonionizing radiation. The situation is the same in other countries as well. Reports indicate that the Soviet Union has proposed that environmental levels of microwave radiation not be permitted to exceed 1 microwatt/cm².[20] However, according to Dr. Pollack (p. 279) the Soviet Union's military services are not required to conform to that limit or to their occupational exposure standard, which prohibits continuous exposure to levels exceeding 10 microwatts/cm². He also noted (p. 279) that research conducted in the Soviet Union and other countries of Eastern Europe, which apparently justified their adoption of these more conservative standards, has not been documented with sufficient detail to permit duplication or confirmation in the United States. On the other hand, Canada has proposed that the maximum exposure level for the general public not be permitted to exceed 1 milliwatt/cm² over the frequency range 10 MHz to 300 GHz.[21]

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[17] See discussion in section III.B.2. of the findings.

[18] The city of New York's Bureau for Radiation Control published on June 22, 1978 a Notice of Intent to limit the maximum permissible power density for radio frequency radiation in the environment to 50 microwatts per square centimeter for all frequencies greater than 10 MHz.

[19] A Technical Review of the Biological Effects of Nonionizing Radiation. A report prepared for the Office of Science and Technology Policy, May 15, 1978, p. 6.

[20] Radiological Quality of the Environment in the United States, 1977, EPA publication No. 520/1–77–009, p. 283.

[21] Microwave Bioeffects and Radiation Safety, Maria A. Stuchly, ed., Transactions of the International Microwave Power Institute, 8 (1978).

The present debate over nonionizing radiation has been characterized by a wide divergence of opinion:

(a) Some persons argue that since long-term exposure to low-levels of nonionizing radiation might be hazardous, strict environmental exposure standards should be established and vigorously enforced until it is proven conclusively that levels of exposure higher than those cited in such a standard are actually safe or that even lower limits are required (Setlow, p. 754).

(b) Others (Mitchell, p. 404; Austin, p. 414; Pollack, p. 283) argue that exposure standards should be based upon concrete evidence of harmful effects.

Significant policy problems often arise when these differing approaches are applied to new products or new applications of microwave technology. For example, should microwave ovens be banned from the marketplace until definitive tests have proven that years of exposure to the low levels of legally permissible leakage from the ovens will indeed be harmless? Could such tests be devised or conducted? Who would pay for them? These questions illustrate the importance of an accelerated and coordinated research program to assess the health effects of nonionizing radiation.

In testimony delivered on June 14, 1978 before the Subcommittee on Communications of the Committee on Commerce, Science, and Transportation, Dr. John W. Lyons of NBS indicated that in addition to its possible biological hazards to humans, nonionizing radiation in the environment cannot only create a nuisance but also affect electrical systems with the potential of causing even greater and more immediate harm. Electronic antiskid brakes, heart pacemakers, military ordnance, and electronic fuel injection systems, as well as TVs and radios, are examples of products that have suffered from electromagnetic interference. Dr. Lyons concluded, "It is clear that the electromagnetic environment must be controlled to allow effective use of communications equipment."

In view of this situation, it is recommended that after completion of its current national survey of ambient nonionizing radiation, EPA should determine whether a mandatory upper limit is needed. In addition, OTA should conduct a study (1) to project the impact of emerging technologies on the levels of nonionizing electromagnetic radiation in the environment and (2) to assess the economic and functional impact of imposing an upper limit on such radiation. (The committee should request authorization of such a study by the Technology Assessment Board of the OTA.)

3. SPECIFIC EXAMPLES OF EXPOSURE AND CONTROL

a. Microwave ovens

Dr. Sherwin Gardner of FDA reported (p. 15) that approximately 1.5 million microwave ovens are sold annually. He estimated that about 11 million units will be in home use in 1980 (p. 16). Tests conducted by BRH in 1970 indicated that 20 percent of the microwave ovens emitted leakage radiation in excess of 10 milliwatts/cm^2 (Gardner, p. 16). In response to this situation, the BRH in 1971 set a microwave oven performance standard which limits the permissible microwave radiation leakage. The limit for new ovens is 1 milliwatt/cm^2, meas-

ured at any point 5 centimeters from the surface of the oven. Ovens in service may degrade to levels no greater than 5 milliwatts/cm^2 at the same distance. The BRH standard also requires that these leakage limits be met under specified damage test conditions. Labels attached to ovens advise consumers to suspend use if damage is visible.

The Association of Home Appliance Manufacturers (AHAM) reported (pp. 422, 429) that according to the American Medical Association's Committee on Occupational Toxicology, the BRH oven standards are 10,000 times below levels known to produce harmful effects. AHAM's representative further testified (p. 422), "With millions of ovens in use, there is not one single injury on record from microwave oven emissions. Many of these ovens have been in use since the 1950's, well before the Federal standards came into being." Nevertheless, a 1976 decision by the Bureau of Radiological Health (docket No. 76 P–0213) caused one manufacturer to recall 36,000 ovens that were suspected of leaking radiation in excess of the 5 milliwatt standdard. (Also, see discussion on p. 427 of the hearing record.) AHAM's president further stated: "The permissible emission levels have not changed since they went into effect in 1971. It is the best judgment of experts in the field that they don't need change."

While it has been reported [22] that microwave ovens have led to injuries including cataracts, skin burns, and sterility, an investigation by committee staff members indicates that no substantiated reports of such injuries have ever been received by the BRH. Manufacturers of microwave ovens are required to report injuries to BRH. In 1977, the Consumer Product Safety Commission investigated two reports of burns associated with microwave ovens; however, the Commission was unable to establish a causal relationship between the claimed injuries and malfunction of the microwave equipment. Additionally, the AMA Committee on Occupational Toxicology cautions (p. 429), "Alleged injury associated with radar radiation cannot be extrapolated to microwave oven exposures because the high-power densities and peak powers used in radar units are far greater than those developed in microwave ovens."

The AMA Committee on Occupational Toxicology has also asserted (p. 429):

> Since it has been demonstrated that high-frequency stimuli may interfere with implanted pacemaker activity, patients with cardiac pacemakers should be warned that proximity to microwave radiation may alter pacemaker function. Reported studies have indicated changes in activity of some pacemakers when patients were within 5 feet of a microwave oven.

A staff investigation (see appendix D) evaluated the availability of any convenient or inexpensive way for the owner of a microwave oven to determine whether radiation leakage exceeds permissible levels, either because of age or damage incurred by the appliance. Microwave oven leakage testing in the home by appliance service establishments is available in metropolitan areas for about $20; it can be expected to be less readily available elsewhere. The status of instrumentation for detecting and measuring microwave signals may be found in appendix D.

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[22] "Microwave ovens: Cooking With Your Fingers Crossed," Paul Brodeur, apf Reporter, volume 1, No. 1, June 1978.

b. High voltage electric powerlines

Mr. Hal Peterson (p. 446) of the NRC identified various effects that have been attributed to high voltage powerlines: production of a toxic gas (ozone), the induction of electrical shock from ungrounded metal structures in the high voltage field of the wires, possible fire hazard due to spark discharges, and annoyances such as radio or TV interference, or acoustical noise. He said that there is also concern about possible neurophysiological effects. James L. Liverman (p. 504) of DOE agreed that if the electric field of a high voltage powerline were strong enough, it could produce neurophysiological effects. However, their occurrence has not been confirmed at the low levels typically encountered (Peterson, p. 447). As in most issues involving nonionizing radiation, the specific details of radiation levels, exposure time, and resulting effects are difficult to quantify.

An experiment conducted over a 1-year period in Jefferson County, Ind., on 765 kV lines running over open, flat cornfields indicated that ozone produced by such lines would be environmentally inconsequential (p. 443). A study by Johns Hopkins Hospital detected no health problems among 11 linemen who were observed for 3½ years. These linemen spent long periods of time in electric fields as strong as 470 kV/m compared to the maximum ground level design limits of 12 kV/m (p. 444).

B. Occupational Exposure

1. EXTENT OF EXPOSURE

The principal sources of worker exposure to microwaves are the heating and drying operations in the food processing, textiles, and forest products industries (Harris, p. 589). NIOSH estimates that over 35 million industrial radio frequency sources are now in use. (See p. 15 of reference cited in footnote 19.) Other sources include the commercial use of microwave ovens and diathermy equipment. Dr. Harris of NIOSH (p. 586) noted that many employers are unaware that their own production equipment utilizes radiofrequency (RF) radiation. For this reason, he explained, estimates of the number of workers exposed to RF and microwave radiation vary between 50,000 and 21 million.

Dr. Harris (p. 587) directed the committee's attention to a NIOSH survey which revealed that 75 percent of the workers using RF sealing and heating equipment were exposed to radiation levels in excess of the present occupational exposure guideline. However, OSHA testified that it never received information from NIOSH to indicate that there were adverse health effects among employees using RF heating and sealing equipment at those exposure levels (Wrenn, p. 578).[23]

2. EXPOSURE STANDARDS

At present (Wrenn, p. 577) there is no legally enforceable limit for occupational exposure to radiofrequency radiation or microwaves. However, OSHA has recommended that power density levels should

[23] Lacking any proof of harmful effects at these levels, OSHA is not empowered under its present voluntary standard to correct the situation, other than by offering recommendations to employers. OSHA could, of course, establish and enforce a mandatory standard.

not exceed 10 milliwatts/cm² (Wrenn, p. 557). This guideline, which is not mandatory, was adopted by the American National Standard Institute (ANSI) in 1966 (Thaler, p. 683) based largely on the earlier DOD Tri-Service research conducted between 1957 and 1961. As explained by Dr. John Osepchuk (pp. 201 and 210), this standard is intended to protect against potentially irreversible thermal damage with a safety factor of at least 10 (also, Schiff, p. 8). This standard places no limit on duration of exposure, thereby ignoring the possibility of cumulative effects (Schiff, p. 8; Rowe, p. 84). ANSI has scheduled a review of its 10 milliwatts/cm² standard for 1979.[24]

NIOSH determined that there has not been sufficient research on the effects of radiation exposure at frequencies between 10 and 200 MHz to validate present exposure guidelines. It is, therefore, difficult to know whether the present allowable exposure levels in this low frequency range are satisfactory (Harris, p. 589).

Standards for occupational exposure to nonionizing radiation in the Soviet Union and Eastern European countries range from 50 to 1,000 times lower than those in the United States.[25] Also, permissible exposure levels decrease as duration of exposure increases (Mitchell, p. 411). Dr. John Osepchuk (p. 210) explained that the Soviet exposure standard includes a safety factor of 100 "to protect against reversible functional disturbances believed to occur for chronic exposure to levels above 1 milliwatt/cm². . . ." Dr. Thaler (p. 683) noted that the Soviet and Eastern European standards were based upon reports that microwave radiation can have observable effects upon the central nervous system and on behavior. Biomedical researchers in the United States are actively investigating the possibility and nature of such behavioral effects.

Canada is currently reviewing a proposal that would limit continuous (8-hour) occupational exposure to microwaves to 1 milliwatt/cm² for frequencies between 10 MHz and 1 GHz and to 5 milliwatts/cm² for frequencies between 1 GHz and 300 GHz. Exposures as high as 25 milliwatts/cm² would be permitted for short periods (less than 2.4 minutes) in either frequency range. No distinction is drawn between continuous and pulsed sources.[26]

It is clear that OSHA, in cooperation with other responsible organizations and Federal agencies, should give priority to a review of the adequacy of its present voluntary standard for occupational exposure to nonionizing radiation. After making any necessary changes, OSHA should promulgate a mandatory standard. While conducting this review, OSHA should consider converting the present voluntary standard to a mandatory standard on an interim basis.

3. IRRADIATION OF U.S. EMBASSY PERSONNEL IN MOSCOW

Dr. Herbert Pollack (p. 269) indicated that for perhaps as long as 24 years, employees of the U.S. Embassy in Moscow have been exposed to very low-level microwave signals. No definitive reasons have been disclosed for Soviet irradiation of this Embassy (Pollack, p. 275).

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[24] Personal communication from Saul W. Rosenthal, chairman, ANSI C-95, Committee on RF Radiation Hazards.

[25] "Trends in Electromagnetic Radiation Bioeffects Research and Related Occupational Safety Aspects", C. H. Dodge and Z. R. Glazer, presented at the International Microwave Power Institute, 1977 Symposium, Minneapolis, Minn., May 24–27, 1977.

[26] Microwave Bioeffects and Radiation Safety, Maria A. Stuchly, ed., Transactions of the International Microwave Power Institute, 8 (1978).

However, U.S. officials knew of the activity for at least 13 years before they informed Embassy employees (Pollack, p. 270).

The Department of State reports that the maximum signal strength outside the building never exceeded 18 microwatts/cm^2 (Pollack, p. 270); the maximum permissible occupational level in the U.S.S.R. is 10 microwatts/cm^2 (Pollack, p. 270). Field strengths inside the building were considerably lower (Pollack, pp. 271 and 276).

In order to determine whether this radiation could cause behavioral effects, DOD in 1965 initiated Project Pandora which exposed monkeys to a synthetic signal much stronger than that encountered by Embassy employees (Pollack, p. 283). In spite of some early, positive indications reported by one of the participating scientists, the Pandora Review Committee concluded that there were no observable behavioral effects (Pollack, p. 283).

Some writers [27] have called attention to alleged specific health problems among State Department employees serving in Moscow, including: (1) chromosome breaks (genetic damage) among returning employees; (2) higher than average number of lymphocytes in blood cell counts among about one-third of the individuals tested; (3) three cases of young children with blood disorders; (4) Ambassador Stoessel's general poor health; and (5) the fact that two of Stoessel's predecessors had died of cancer. However, after investigation, the State Department concluded that no radiation-related health problems could be detected among personnel who served at the U.S. Embassy in Moscow (Pollack, p. 278). In addition, the Department of State in March 1976 asked the Johns Hopkins University to conduct an epidemiological study of employees exposed to the Moscow signal (Pollack, p. 271). The results of that study were released on November 20, 1978 and indicated that personnel working at the American Embassy in Moscow between 1953 and 1976 suffered no apparent ill effects from the Soviet Union's microwave bombardment of the Embassy during those 23 years. In particular, there was no extraordinary incidence of cancer, brain disorders, or loss of vision in any of the Embassy personnel scrutinized in the Johns Hopkins study.

DOD has provided the committee with a detailed accounting of the destruction in September 1973 of nearly all of the classified notebooks, research protocols and 16mm films relating to Project Pandora. The unclassified data, however, have been located and turned over to the committee. DOD testified that it has no classified research underway on the medical effects of electromagnetic radiation. All prior research has been declassified (Austin, p. 413). Further investigation of the Moscow Embassy situation by the committee is underway. A separate report will be issued summarizing the results of that investigation.

C. Status of Bioeffects Research

1. General observations

Mr. Daniel Cahill of the EPA (p. 85) indicated that little is known about what biological effects may be produced by long-term, low-level exposure to nonionizing radiation. He noted that even less is known

[27] For example, see the Zapping of America, Paul Brodeur, W. W. Norton and Co., New York (1977).

about the effects of low-level electric fields. Capt. Frank Austin (p. 312) added that the need to understand these effects more fully has drawn the attention of consumer protection groups, environmentalists, regulatory agencies, legislators, and scientists around the world. He also mentioned that there is still controversy within the scientific community over the question of safe or acceptable levels. Currently available research results are not sufficient to resolve that controversy.

The research problem is complex and multifaceted. Major Larsen (p. 338) pointed out that in order to assess the biological effects of nonionizing radiation, the power, frequency, duration, modulation, and geometry of the radiation must be considered in conjunction with the geometry, energy-absorbing capacities, induced electromagnetic fields, temperature rise, and the specific organs, tissues, cells, or molecules involved in the biosystem receiving the radiation.

Different microwave frequencies can couple with different parts of the body. Thus, the amount of energy absorbed by a particular region of the body depends, among other things, upon the match between the size and orientation of the specific body component with the wavelength of the incident radiation (Larsen, pp. 338 and 352). Furthermore (Thaler, p. 684), the differences in size and mass between humans and laboratory animals are among the many factors which need to be considered in assessing or interpreting such research. This greatly complicates the transferability of research findings from small laboratory animals to humans. As pointed out by Dr. Osepchuk (p. 201), some researchers believe that there are real thresholds for damage by nonionizing radiation, and that no truly cumulative effects exist. He could find no evidence that long exposure to radio or television broadcast signals is harmful.

According to Dr. Richard Setlow (p. 753), who testified for the National Academy of Sciences, measurement problems account for some of the difficulties in conducting research on the biological effects of nonionizing radiation. For example, Dr. Setlow noted that while dosimeters are used to measure the intensity of ionizing radiation to which individuals are exposed, no comparable instruments exist to measure microwaves. For this reason, Dr. Setlow believes that attempts to assess the exposure of a particular population to microwave radiation produce only crude averages; individual exposure can vary considerably from these averages. The lack of accurate portable survey instruments[28] to measure RF radiation near its source (the "near field" region) is a serious problem for industry, researchers, and regulatory agencies (Harris, p. 587). Also, nonionizing radiation's effects on simple molecules and cells are usually more difficult to perceive than are the effects of ionizing radiation (Setlow, p. 753).

Dr. Ambler of NBS (p. 1179) also commented that accurate measurement systems do not exist for nonthermal effects research and that measurement methods and standards do not exist or are inadequate for measuring complex electromagnetic fields such as those generated by pulsed signals and multiple-source environments. Since the capability to make accurate and reliable radiation measurements is fundamental to both researchers and regulators, NBS should intensify its efforts to provide the physical measurement standards, calibration

[28] See appendix D for a detailed review of the availability of such measuring instruments.

services, and standardized measurement techniques necessary for research and regulatory activities relating to nonionizing radiation.

Understanding the physiological mechanisms responsible for the biological effects of long-term exposure to microwave radiation is difficult. Because of the large number of parameters involved and the wide range of values that each may assume, Dr. Paul Tyler concluded (p. 358):

> It is easy to see why nonionizing electromagnetic radiation is far more complex than ionizing radiation. To complicate matters even further, the various portions of the spectrum require different radiating and exposure facilities.

Not all biological changes or observed effects which result from exposure to low levels of nonionizing radiation are necessarily harmful, e.g., perception of a radiation field such as "hearing" radar or feeling heat (Schiff, p. 8; Villforth, p. 25; Osepchuk, p. 204).

As measured by the total level of effort, research on the health effects of nonionizing radiation has been given an unacceptably low priority throughout the Federal establishment. Only about $9 million are spent each year for research on the biological effects of nonionizing radiation (Thaler, p. 687).

2. SOME SPECIFIC FINDINGS AND AREAS OF INVESTIGATION

Exposure of laboratory animals to nonionizing radiation can produce measurable biological effects such as increased body temperature or changes in heart rhythms, cell growth rates, and cellular rates of metabolism (Schiff, p. 6; Villforth, p. 25; and Larsen, p. 340). Dr. Thaler noted (p. 684) that some researchers who have exposed small animals to microwave radiation at or below 10 milliwatts/cm^2 have observed changes in learned behavior or task performance, radiation perception (e.g., hearing microwaves), and alterations in electrophysical measurements of nervous system activity. It is worth repeating that Dr. Schiff (p. 8), Mr. Villforth (p. 25), and Dr. Thaler (p. 684) all emphasized that such effects do not necessarily imply risk to individuals exposed at these levels.

Some studies indicate that exposure of pregnant animals to microwave radiation may harm the fetus (Harris, p. 587). For example, in one experiment conducted by the Stanford Research Institute,[29] squirrel monkeys were exposed to microwave levels not exceeding 10 milliwatts/cm^2 for about 6 months before and after birth. While no physical changes had been observed, several of the young monkeys died within 6 months of their birth. Animal experiments conducted by the National Institute for Environmental Health Sciences (NIEHS) showed no gross deformities resulting from exposure of developing embryos to microwave radiation at the 5 milliwatts/cm^2 level, but statistically significant effects on hemoglobin and white cell numbers were reported (Rall, p. 668). Pulsed electromagnetic signals have produced greater biological effects than continuous ones.

The AMA Committee on Occupational Toxicology asserts (p. 429):

> Microwave exposure can cause skin burns and may affect the eyes and other organs. Exposure directed at the eyes of rabbits has resulted in various ocular effects, including cataracts, while direct exposure of the testes of rats has led to degenerative changes. Cataracts have been produced in some men engaged in

[29] Personal communication with Dr. Joel Kaplan, Stanford Research Institute, Menlo Park, Calif. 94025.

the manufacture, servicing, or repair of microwave (radar) generating units. Alleged injury associated with radar radiation cannot be extrapolated to microwave oven exposures because the high-power densities and peak powers used in radar units are far greater than those developed in microwave ovens.

U.S. Army research has found no correlation between occupational microwave exposure and formation of cataracts (Larsen, 340). However, Navy-sponsored research (Tyler, p. 359) has shown that cataracts can be produced by microwaves if the radiation level is strong enough to raise the internal temperature of the eye to 45 degrees Celsius (113 degrees Farenheit).

In addition, the AMA Committee on Occupational Toxicology notes (p. 428):

Biological effects resulting from excessive exposure to certain microwave frequencies are not completely understood. The effects of heating has been extensively studied. The body feels heat at a level far below that necessary to cause injury during short exposures. Some researchers have suggested that biological changes may be produced at much lower levels of microwave energy densities than those which cause heat effects.

Capt. Paul Tyler (p. 420) testified that studies of the effects caused by the extremely low frequency radiation generated by the Navy's Project Seafarer have demonstrated (1) an alteration of the calcium binding parameters of the membranes of the brain at field strengths 800 times stronger than the Seafarer signal and (2) a modification of the growth parameters for primitive single-celled organisms called slime mold at levels two to three times that of Project Seafarer. Project Seafarer uses radiation at 45, 60, and 76 hertz (far below the microwave frequencies) and field strengths of 0.07 volts/meter.[30] When such fields are compared to the 12,000 volts/meter design limits for high voltage transmission lines, it is easy to understand why the National Academy of Sciences [31] concluded that these fields should not cause a significant and adverse biological disturbance. As with most other radiation issues, however, there is enough uncertainty for the Academy to suggest continuing research.

While evidence is mounting in U.S. laboratories that there may be cumulative damage from low levels of exposure to nonionizing radiation (Schiff, p. 7 and Gardner, p. 19), no firm conclusions can yet be drawn (Setlow, p. 757). Additional research is clearly required.

3. RESEARCH NEEDS

Dr. William J. Thaler, then Acting Director, Office of Telecommunications Policy, Executive Office of the President, offered the following research priorities for nonionizing radiation (p. 685): First, experiments to investigate effects of long-term, relatively low-level exposure; second, studies of people exposed in specific occupations or experimental circumstances; third, increased investment in basic research, including investigations of mechanisms of biological interaction; and fourth, additional development and refinement of techniques for computing comparable doses of radiation, for measuring internal energy fields and energy distribution, and for relating labora-

[30] At low frequencies, where wavelengths may extend to many thousands of miles, it is easier to independently measure the strength of oscillatory electric and magnetic fields than to make a combined measurement of power density.

[31] Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer, National Academy of Sciences (1977).

tory findings on animals to effects on man. These priorities are consistent with the findings of this report, and should receive careful consideration by those responsible for allocating research funds.

Dr. Donald McRee (p. 669) of the NIEHS explained that as part of the joint United States/U.S.S.R. Agreements on Scientific and Technical Cooperation, identical experiments on the biological effects of long-term low-level exposure to microwave radiation were to be conducted in both countries. Microwave radiation at the level of 500 microwatts per square centimeter was to be used to look for behavioral and biochemical changes in animals. It was hoped that these experiments would resolve some of the discrepancies between United States and U.S.S.R. findings which have appeared in the scientific literature. Although the project was scheduled to be completed in fiscal year 1978, investigation by the committee staff revealed that only limited funding has been available for conducting this joint research. As a result of this inadequate funding, the U.S. researchers are able to pursue only short-term projects. It is important that the long-term, low-level studies begin as soon as possible. In addition, the Committee on Commerce, Science, and Transportation should review the overall mechanism for planning, conducting, and managing joint studies of this type.

Capt. Paul Tyler, speaking on behalf of the U.S. Navy, pointed out (p. 360) that scientific proof of any link between microwave exposure and a resulting disease can be demonstrated in either of two ways—laboratory research or epidemiological studies. He believes that while case studies may be useful in identifying effects to look for, they do not provide scientific evidence of cause and effect. Unfortunately, as stated by Dr. Thaler (p. 685), research into long-term chronic exposure and comprehensive epidemiological studies both require large and stable funding levels that are probably beyond the financial resources of any single Government agency.

In addition to answering some of today's most pressing questions of radiation health and safety, a vigorous program of research into the biological effects of nonionizing radiation might lead to the development of new medical, biological, or even agricultural applications, and produce secondary uses for industry (Osepchuk, p. 214).

D. Ultrasonic Radiation

According to Dr. Elliott S. Harris (p. 588) jet airplanes and ultrasonic cleaners and welders are the principal sources of industrial exposure to ultrasonic radiation. Dr. Harris also noted that there are no exposure standards relative to the industrial use of ultrasonic radiation. He identified the diagnosis of cancer and defining the position of a fetus as the principal medical uses of ultrasonic radiation.

The BRH and other laboratories have been conducting both laboratory and epidemiological research on the potential biological effects of ultrasound (Gardner, p. 40). Dr. Gardner (p. 19) indicated that acute exposure to ultrasound has been shown to cause physical defects in rodents and to initiate blood clotting in the region of application. Chromosome aberrations and altered growth rates have been seen in plant cells and roots (Gardner, p. 40).

In view of the increasing use of ultrasound, further research should be undertaken to permit an analysis of its potential risks and benefits.

Furthermore, it is recommeded that OSHA, in cooperation with NIOSH, assess the need for standards to control occupational exposure to ultrasound, and that BRH assess the need for standards to control medical uses of ultrasound.

IV. JURISDICTIONAL PROBLEMS

A. Gaps and Overlaps

The Library of Congress has identified 17 major Federal agencies that have at least some radiation health and safety authority, as follows:

Nuclear Regulatory Commission.—Safety facilities for handling nuclear materials; public and occupational safety; oversight of the use of radioisotopes in nuclear medicines and industry.

Department of Energy (formerly the Energy Research and Development Administration).—Ionizing and nonionizing radiation research related to hazards; biological effects; safety standards.

Department of Defense (Army, Navy, Air Force).—Health effects of nuclear laser weapons, microwave, and emitting devices; radiological safety; civil defense.

Environmental Protection Agency (Office of Radiation Programs).—Control and monitoring of ionizing and nonionizing radiation in the environment; establishment of safety and exposure standards.

Veterans Administration.—Diagnostic and therapeutic applications of ionizing and nonionizing radiation.

Department of Commerce (National Bureau of Standards).—Establishment of standards for radiation measurement. Also (*National Telecommunication and Information Agency*) broad overview of Federal research and development programs related to the biological effects of nonionizing radiation.

Department of Health, Education, and Welfare [National Institutes of Health (NIEHS, NIDR, NIGMS, NCI, etc.): National Institute for Occupational Safety and Health].—Biological effects and medical applications of ionizing and nonionizing radiation; occupational safety and health standards. Also [*Food and Drug Administration (Bureau of Radiological Health)*]—Protection of the public from radiation-emitting electronic products; establishment of exposure standards.

Department of the Interior (Mining Enforcement and Safety Administration).—Health and safety aspects of uranium mining.

Department of Transportation (Federal Aviation Administration, Federal Railroad Administration, Materials Transportation Bureau, U.S. Coast Guard.)—Safety aspects of the transportation of radioactive materials.

Interstate Commerce Commission.—Safety aspects of the transportation of radioactive materials.

National Transportation Safety Board.—Safety aspects of the transportation of radioactive materials.

Department of Labor (Occupational Safety and Health Administration).—General occupational safety and health of personnel, including those working around radiation sources.

National Aeronautics and Space Administration.—Ionizing and nonionizing safety and health as related to space programs.

United States Postal Service.—Safety of radioactive materials in the mails.

Consumer Product Safety Commission.—Safety aspects of luminous dials on watches.

Department of Agriculture.—Radiation contamination of crops; uses of radiation to control pests.

National Science Foundation.—A limited amount of research on the biological effects of nonionizing radiation.

To more clearly indicate the gaps and overlaps that exist in agency jurisdiction, Mr. Chris Dodge of the Congressional Research Service, the Library of Congress, assembled the following charts:

GENERAL OVERLAP OF FEDERAL RESEARCH, REGULATORY, AND DEVELOPMENT PROGRAMS CONCERNED WITH NONIONIZING RADIATION

Year	1	2	3	4	5	6	7	8	9	10	11
1968	Navy, AF, NIH, ARPA, Army.	Navy	AF, Army	NIOSH, AF, FCC, Army, OTP.	AF	FAA, NIOSH, AF, NIH, Army.	NIH, Army		Navy	Navy, AF, Army.	NBS, Army.
1969	Navy, AF, NIH, ARPA, FDA, Army.	do	MESA, AF, FDA, Army.	NIOSH, Navy, MESA, AF, FCC, FDA, Army, OTP.	MESA, AF	do	do	MESA	do	Navy, AF, Army, FDA.	Do.
1970	do	do	do	do	MESA, AF, FDA.	FAA, AF, NIH, FDA, Army.	do	MESA	do	do	NBS, FDA, Army.
1971	do	do	OSHA, MESA, AF, Army.	Navy, MESA, AF, FCC, FDA, OTP, Army.	MESA, AF, FDA.	do	do	MESA	do	do	NBS, FDA, Navy, Army.
1972	Navy, AF, NIH, EPA, FDA, DNA/AFRRI.	do	OSHA, NIOSH, NBS, MESA, AF, Army.	NIOSH, Navy, MESA, AF, FCC, FDA, OTP, Army.	MESA, AF, FDA.	FAA, NIOSH, Navy, AF, NIH, Army.	do	MESA	do	Navy, AF, Army, FDA, DNA–AFRRI.	NBS, FDA, VA, Navy, Army.
1973	Navy, AF, NIH, EPA, FDA, DNA–AFRRI, Army.	do	OSHA, NBS, MESA, AF, FDA, Army.	do	MESA, AF, FDA.	FAA, NIOSH, Navy, AF, NIH, FCC, Army.	do	FAA, Navy, MESA, EPA.	Navy, EPA	do	NBS, VA, Army, Navy.
1974	NIOSH, Navy, AF, NIH, EPA, FDA, DNA AFRRI. Army	do	do	NIOSH, OSHA, Navy, MESA, AF, FCC, FDA, Army.	OSHA, MESA, AF, FDA.	FAA, NIOSH, OSHA, Navy, AF, NIH, FCC, Army.	do	MESA, EPA, Navy, FAA.	NBS, EPA, Navy.	do	NBS, FDA, VA, FAA, Navy, Army.
1975	do	do	do	NIOSH, OSHA, Navy, MESA, AF, FCC, OTP, Army.	OSHA, MESA, AF, FDA.	FAA, NIOSH, OSHA, Navy, AF, NIH, FCC, FDA, Army.	do	FAA, Navy, MESA, EPA	Navy, NBS, EPA.	do	Navy, NBS, VA, FDA, Army.

1976	NIOSH, Navy, AF, NIH, VA, EPA, FDA, DNA-AFRRI, Army.	do	do	NIOSH, OSHA, Navy, MESA, AF, FCC, FDA, OTP, Army.	OSHA, MESA, AF, FDA.	do	NIH, VA, Army.	Navy, MESA	Navy, NBS, EPA.	do	Do.
1977	do	do	do	do	OSHA, MESA, AF, FDA.	FAA, NIOSH, OSHA, Navy, AF, NIH, VA, FCC, FDA, Army.	do	MESA	Navy, NBS, EPA, Army.	do	NBS, VA, Navy, FDA.
1978	FAA, NIOSH, AF, NIH, VA, EPA, FDA. DNA-AFRRI, Army.	do	do	do	MESA, AF, FDA.	NIOSH, OSHA, FAA, Navy, AF, NIH, VA, FCC, FDA, Army.	do	MESA	EPA, Army	Army, FDA, DNA-AFRRI.	FDA.

Key:
1. Human health effects research.
2. Ecological effects (plant, animal).
3. Criteria/standards development.
4. State/Federal liaison.
5. Licensing, certification, inspection.
6. Monitoring/surveillance.
7. Medical, diagnostic, therapeutic.
8. Collection/analysis of health data.
9. Collection/analysis of environmental data.
10. Miscellaneous biological/physical effects.
11. Other studies.

Abbreviations:
AF—Air Force.
ARPA—Advanced Research Projects Agency, DOD.
DNA-AFRRI—Defense Nuclear Agency-Armed Forces Radiological Research Institute.
EPA—Environmental Protection Agency.
FAA—Federal Aviation Administration, DOT.
FDA—Food and Drug Administration (Bureau of Radiological Health).
FCC—Federal Communications Commission.
MESA—Mine Enforcement and Safety Administration.
NBS—National Bureau of Standards.
NIH—National Institutes of Health.
NIOSH—National Institute for Occupational Safety and Health.
OSHA—Occupational Safety and Health Administration.
OTP—Office of Telecommunications Policy.
VA—Veterans' Administration.

GENERAL OVERLAP OF FEDERAL RESEARCH, REGULATORY, AND DEVELOPMENT PROGRAMS CONCERNED WITH IONIZING RADIATION

Year	1	2	3	4	5	6	7	8	9	10	11	12	13
1968	FAA, NIOSH, AF, Navy, AEC, DNA–AFRRI	NIH, AEC.	USDA	NBS, AF, MTB	AF, MTB	Army	FAA, NBS, AF, NIH, USDA, Army.	NBS, NIH, AEC, Army.	DNA–AFRRI, Army.	AF, Army	DNA–AFRRI, NBS, AEC, Army.	NBS, NIH, AEC, Army, DNA–AFRRI.	
1969	FAA, NIOSH, AF, Navy, NIH, AEC, FDA, DNA–AFRRI.	NIH, AEC.		NBS, MESA, AF, MTB, FDA.	MESA, AF, MTB.	MESA, FDA, Army.	NBS, AF, NIH, USDA, Army.	do	MESA, Army, DNA–AFRRI.	MESA, AF, Army.	DNA–AFRRI, NBS, AEC, FDA, Army.	MESA, NBS, NIH, AEC, FDA, Army, DNA–AFRRI.	
1970	FAA, NIOSH, Navy, AF, NIH, AEC, FDA, DNA–AFRRI.	AEC		NBS, MESA, AF, MTB, FDA, Army.	MESA, AF, MTB, FDA,	do	NBS, AF, NIH, USDA, FDA, Army.	do	do	do	NBS, AEC, FDA, Army, DNA–AFRRI.	NBS, MESA, NIH, AEC, FDA, DNA, Army.	
1971	FAA, NIOSH, AF, NIH, AEC, FDA, DNA–AFRRI.	AEC		OSHA, NBS, MESA, AF, MTB, FDA, Army.	NIOSH, MESA, AF, MTB, FDA.	do	do	do	do	do	do	NBS, MESA, NIH, AEC, FDA, Army, DNA–AFRRI.	
1972	FAA, NIOSH, AF, NIH, AEC, EPA, FDA, DNA–AFRRI.	AEC	USDA	OSHA, NBS, AF, MESA, MTB, FDA, Army.	NIOSH, MESA, AF, MTB, FDA.	do	NIOSH, Navy, NBS, AF, NIH, USDA, FDA, Army.	do	do	do	do	NBS, MESA, NIH, AEC, FDA, DNA–AFRRI.	
1973	do	AEC		do	NIOSH, MESA, AF, MTB, EPA, FDA.	do	do	NBS, NIH, AEC, EPA, Army.	MESA, EPA, Army, DNA–AFRIR.	MESA, EPA, AF, Army.	do	NBS, MESA, NIH, AEC, EPA, FDA, DNA–AFRRI.	
1974	FAA, AF, NIH, AEC, EPA, FDA, NASA, DNA–AFRRI.	AEC		OSHA, NBS, MESA, AF, MTB, FDA, Army,	NIOSH, OSHA, MESA, AF, MTB, EPA, FDA,	OSHA, MESA, FDA, Army.	NIOSH, OSHA, AF, Navy, NBS, NIH, USDA, Army.	do	MESA, EPA, Army, DNA–AFRRI.	do	NBS, AEC, NASA, Army DNA–AFRRI.	NBS, MESA, NIH, AEC, EPA, FDA, DNA–AFRRI,	

1975	FAA, NIOSH, AF, NIH, AEC, EPA, NASA, ERDA, DNA–AFRRI.	ERDA		OSHA, NBS, MESA, AF, MTB, NRC, Army.	NIOSH, OSHA, NBS, MESA, AF, MTB, NRC, EPA, FDA.	OSHA, MESA, NRC, FDA, Army.	NIOSH, OSHA, Navy, NBS, AF, NIH, NRC, USDA, FDA, Army.	NBS, NIH, NRC, AEC, EPA, Army.	do	do	NBS, AEC, FDA, NASA, Army, DNA–AFRRI.	NBS, MESA, NIH, AEC, EPA, FDA, DNA–AFRRI.	NRC
1976	FAA, NIOSH, AF, NIH, NRC, ERDA, EPA, FDA, NASA, DNA–AFRRI.	NRC, ERDA.	NRC, USDA.	OSHA, NBS, AF, MESA, MTB, NRC, ERDA, EPA, FDA, Army.	NIOSH, OSHA, NBS, MESA, AF, MTB, NRC, EPA, FDA.	do	NIOSH, OSHA, Navy, NBS, AF, NIH, NRC, ERDA, USDA, Army.	NBS, NIH, NRC, ERDA, EPA, Army.	MESA, NRC, EPA, Army, DNA–AFRRI.	MESA, AF, NRC, EPA, Army.	NBS, ERDA, FDA, NASA, DNA–AFRRI.	NBS, MESA, NIH, ERDA, EPA, FDA, DNA–AFRRI.	NRC
1977	do	NRC, ERDA.	NRC, USDA.	do	NIOSH, OSHA, NBS, MESA, AF, MTB, NRC, EPA, FDA.	do	NIOSH, OSHA, Navy, NBS, AF, NIH, NRC, ERDA, FDA, Army.	NBS, NIH, NRC, ERDA, EPA, Army.	MESA, NRC, Army, DNA–AFRRI.	do	NBS, ERDA, FDA, NASA, DNA–AFRRI.	NBS, MESA, NIH, ERDA, EPA, FDA, DNA–AFRRI.	NRC
1978	FAA, NIOSH, AF, NIH, NRC, ERDA, FDA, NASA, DNA–AFRRI.	NRC, ERDA.	NRC, USDA.	OSHA, NBS, MESA, AF, MTB, NRC, ERDA, EPA, FDA, Army.	NIOSH, OSHA, NBS, MESA, AF, MTB, NRC, EPA, FDA.	do	Navy, NBS, AF, NIH, NRC, ERDA, USDA, FDA, Army.	NBS, NIH, ERDA, EPA, Army.	do	do	NBS, ERDA, FDA, NASA, DNA–AFRRI.	NBS, MESA, NIH, ERDA, EPA, FDA, DNA–AFRRI.	NRC

Key:
1. Human health effects research.
2. Ecological effects (plant, animal).
3. Agricultural effects (plant, animal).
4. Criteria/standards development.
5. State/Federal liaison.
6. Licensing, certification, inspection.
7. Monitoring/surveillance.
8. Medical, diagnostic, therapeutic.
9. Collection/analysis of health data.
10. Collection/analysis of environmental data.
11. Miscellaneous biological/physical effects.
12. Other studies.
13. Reactor safety environmental surveys.

Abbreviations:
AEC—Atomic Energy Commission.
AF—Air Force.
ARPA—Advanced Research Projects Agency, DOD.
DNA–AFRRI—Defense Nuclear Agency-Armed Forces Radiological Research Institute.
EPA—Environmental Protection Agency.
ERDA—Energy Research and Development Agency.
FAA—Federal Aviation Administration.
MESA—Mine Enforcement and Safety Administration.
MTB—Materials Transportation Bureau.
NBS—National Bureau of Standards.
NIH—National Institutes of Health.
NIOSH—National Institute for Occupational Safety and Health.
NRC—Nuclear Regulatory Commission.
OSHA—Occupational Safety and Health Administration.
USDA—U.S. Department of Agriculture.

This confusing Federal picture led the Conference of Radiation Control Program Directors to conclude (p. 732) "In light of the many Federal agencies having responsibility in radiation protection, there are areas of duplication, and in many cases, what appears from the States' viewpoint confusion at the Federal level on matters relating to radiation protection." The conference (p. 732) identified the dual efforts of FDA and EPA to develop X-ray standards ". . . as an example of how various agencies present a confused position to the States." In testimony before the House Subcommittee on Health and the Environment on July 13, 1978, the chairwoman of the conference indicated that States sometimes find different Federal agencies writing different and occasionally conflicting standards to cover the same area. Similar complaints were received from Mrs. Kushner (p. 123) and Dr. Morgan (p. 241).

Mr. Lee V. Gossick of the NRC (p. 433) told the committee that no Federal agency has been given direct responsibility for controlling naturally occurring or accelerator-produced radioactive materials of commercial value, although some States (Hardin, p. 712) do exercise surveillance over these sources. Mr. Gossick reported that a task force analyzing this subject had suggested that the NRC seek legislative authority to regulate the use of these materials. This area was also identified by the Conference of Radiation Control Program Directors (Hardin, p. 712) as possibly requiring Federal legislation in order to achieve uniform control of this type of radioactive material. The conference spokesman (Hardin, p. 712) pointed out, for example, that radium, a naturally occurring radioactive element not included under the Atomic Energy Act, may represent as much of an exposure hazard to the population as any of the materials covered by the act. The conference also believes that research equipment which produces ionizing or nonionizing radiation should be subjected to the same rules and regulations (e.g., relating to radiation leakage) that apply to equipment designed for industrial, medical, and other uses (Hardin, p. 711). We recommend that a coordinated Federal program be established to identify, assess, and, if necessary, regulate the exposure hazard from any radioactive materials (such as those produced by cyclatrons or radiation emitting equipment, which are not now within the jurisdiction of the NRC or other Federal agencies.

Another problem was identified in comments furnished by the National Bureau of Standards, Acting Director, Dr. Ernest Ambler (p. 1177). According to NBS, "One of the most serious deficiencies in the present system is the lack of organizations or institutions which can and will operate at the intermediate level," that is, between NBS and the State, county, city, and other user categories. NBS finds itself "physically incapable of calibrating the large numbers of existing field instruments." They stress that ". . . intermediate levels of calibration services are required for an effective national system." In order to provide the committee with a better understanding of the specific problems involved and the possible solutions, it is recommended that NBS, in cooperation with the Conference of Radiation Control Program Directors, review the need for an intermediate level of calibration services, such as regional facilities to better couple NBS laboratories with State and industrial needs.

B. Coordination of Bioeffects Research

Since 1967, the Electromagnetic Radiation Management Advisory Council (ERMAC) has served as a central focus for the review of scientific knowledge, requirements, the status of programs, and funding levels in nonionizing radiation research. ERMAC recommends guidelines, research priorities, and increased funding for a coordinated program of investigation among responsible Federal departments (Thaler, p. 683). Witnesses found this to be a useful activity which significantly enhanced the effectiveness of limited resources (e.g., Cahill, p. 83, Pollack, p. 280, Rall, p. 672). Until February 1978, ERMAC was an advisory body to the Office of Telecommunications Policy (OTP) in the Executive Office of the President. It has now been moved with OTP to the National Telecommunications and Information Agency (NTIA) within the Department of Commerce. Since ERMAC had neither the authority to set agency priorities nor to establish budgets for nonionizing radiation research (Thaler, p. 688), its major accomplishment has been improved communication and coordination among participants.

There is a clear need for a mechanism to continue coordinating all Federal research on the biological effects of nonionizing radiation. Witnesses were unanimous in their opposition to having a single Federal agency charged with performance of radiation research (e.g., Austin, p. 311; Pollack, p. 280). They felt that a centralized research effort might become excessively ingrown and less imaginative (e.g., Rall, p. 672).

Throughout a 50-year history of research activity dealing with the biological effects of ionizing radiation, little evidence of formal coordination was found.[32]

C. Possible Solutions

The foregoing testimony indicates that the Government's total effort lacks coordination and direction. A study published in December 1977 by the Senate's Governmental Affairs Committee recommended that EPA be given powers in the field of radiation safety similar to those it already possesses for control of toxic substances, that is, to serve as a central focus for all radiation protection activities. With such authority, EPA could request action from another agency, set deadlines for the other agency's action, and intervene to establish enforceable standards if its deadlines were not met. However, a survey published in August of 1978 by the Governmental Affairs Committee found no support among informed groups and individuals in the private sector for assigning lead-agency responsibility either to EPA or any other single agency. Additionally, a General Accounting Office report (CED–78–27) issued on January 20, 1978, recommends that the Congress define more clearly EPA's role as the Federal overseer of environmental radiation protection and also that it define the scope of radiation dangers to be addressed by the Agency.

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[32] On May 9, 1978, Presidential Assistants Stuart Eizenstat and Zbigniew Brzezinski announced the President's decision to have the Secretary of Health, Education, and Welfare coordinate the formulation of a broad program to study the biological effects of exposure to ionizing radiation. HEW has established a task force to carry out this directive. Its recommendations are expected early in 1979.

Witnesses before the Committee on Commerce, Science, and Transportation were divided on the question of whether there should be a single agency or even a single "lead agency" to coordinate or direct all radiation regulatory activities (e.g., Gossick, p. 434; Taylor, p. 137; Hardin, pp. 705 and 742). However, all witnesses supported a clearer definition of the specific authority of each agency, and guidelines for judging the acceptability of risks (e.g., Kushner, p. 123; Austin, p. 311). Some have suggested reestablishing the Federal Radiation Council, perhaps with some modifications (e.g., Taylor, p. 152).[33]

Given the complexity of existing organizational problems, it will be difficult to develop a solution that is totally satisfactory to all parties. However, on the basis of the hearing record and subsequent investigations, there appear to be three actions which are fundamental to correcting the present organizational deficiencies:

A. The President should resolve at the earliest practical date the jurisdictional ambiguities in Federal agency responsibilities which prevent a coordinated approach to radiation research and regulation. This effort should be coordinated with those committees of Congress which have legislative and oversight jurisdiction over these activities.

B. The President should establish an executive-level position within the Executive Office of the President with the sole responsibility of providing sustained coordination of the multiagency radiation research and regulatory effort. While we do not intend to indicate the detailed support structure for this position, it is essential that it have the following capabilities:

Authority to decide among competing jurisdictional and regulatory activities of the various agencies;

Authority to involve representatives of affected agencies on a regular basis;

Direct access to the President in implementing decisions regarding agency roles and responsibilities; and

Adequate staff to carry out these responsibilities.

This coordinating mechanism should provide for Presidential-level review of agency performance and direction of agency responsibilities, priorities, and funding levels. It is essential that the present situation of jurisdictional ambiguity and overlapping not be permitted to recur once the existing problems have been rectified.

C. The coordinating mechanism established above should make extensive use of existing advisory bodies—specifically the National Academy of Sciences/National Research Council's Committee on Biological Effects of Ionizing Radiation and the Department of Commerce's Electromagnetic Radiation Management Advisory Council. These panels can assist in evaluating present research activities and in establishing priorities among those areas of research which need additional attention. In addition, medical and industrial users of radiation, electronic product manufacturers, the nuclear industry, employee representatives, the radiation research community, and members of the affected public should be consulted in reviewing the radiation protection performance of Federal agencies, and in assigning agency responsibilities and priorities.

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[33] These questions have also been addressed at hearings before the House Committee on Government Operations on April 18 and 19, 1978, and on July 13, 1978.

SUMMARY OF TESTIMONY

Dr. Stefan O. Schiff, genetics program, Department of Biological Sciences, George Washington University, identified the differences between ionizing and nonionizing radiation, and discussed the microscopic nature of effects that each can have on biological systems. He pointed out, for example, that X-rays, gamma rays and other kinds of ionizing radiation can knock electrons out of atoms, break chemical bonds, and cause chromosome breaks. Dr. Schiff said, "These physical and chemical changes in turn lead to the production of biological changes which usually appear at a somewhat later time . . . sometimes days or weeks after the radiation." He explained that the damage produced by ionizing radiation is of major concern when genetic material is altered or destroyed. There is no problem if the cell, which contains altered genes, should die. But, if the cell survives and reproduces, it could give rise to a host of other abnormal cells which subsequently are responsible for the initiation of a disease process such as leukemia. Mutations in reproductive cells are of particular concern because defects occurring in these cells can be transmitted to future generations. Unfortunately, the thresholds for damage from specific kinds of ionizing radiation have not been established for humans, and serious quantitative problems arise when one tries to extrapolate animal data to humans.

Dr. Schiff's discussion of nonionizing radiation was concerned primarily with microwaves, whose effects, he said, are mostly thermal in nature and in many cases reversible. Dr. Schiff indicated that some additional and probably nonthermal microwave effects have been reported at power densities lower than 10 mW/cm^2, the recommended upper limit for occupational exposure. He reported: "A host of behavioral changes have been produced by chronic exposure to low-power densities such as 1 mW/cm^2 according to some Soviet and Eastern European data. This is for both animals and humans." However, Dr. Schiff cautioned: ". . . a satisfactory explanation as to how such effects might be produced is lacking at the present time. There are some theories, but none are substantial experimentally. Insofar as biological effects are concerned, most of the data come from experimental studies with a variety of mammals." As with ionizing radiation, Dr. Schiff finds, "It's very difficult to determine thresholds for microwave effects. . . ." Also, he added, "The extrapolation of data from experimental animals to humans is very risky . . . because the exposure conditions are so extremely different." At sufficiently high power level and sufficiently long exposure, Dr. Schiff believes that microwaves could cause cataracts or even death.

Dr. Schiff concluded his statement by identifying two possible problems with the current U.S. microwave exposure standard:

1. There is no time limit on exposure; this ignores possible cumulative effects.
2. Some effects may be possible below 10 mW/cm^2.

In the discussions which followed his formal statement, Dr. Schiff expressed his concern "over the voluminous reports in the Soviet literature which indicate that there are all sorts of effects at very low exposure doses to microwaves." He felt that attempts should be made to duplicate these experiments "to see if they are reproducible."

With regard to ionizing radiation Dr. Schiff believes there is a need to balance the risks and benefits involved with the use of medical X-rays either for diagnosis or for therapy. He cautioned:

> * * * there is always a conceivable possibility that a diagnostic X-ray can initiate a severe disease process. But the chance of that occurring is so slight that it would be foolish to cut out that type of diagnostic procedure, which would be of great benefit to a patient, just because there is a potential risk that some radiation damage may occur.

Dr. Sherwin Gardner, Deputy Administrator of the Food and Drug Administration, described FDA's activities to protect public health through enforcement of the Radiation Control for Health and Safety Act of 1968. Acting through the Bureau of Radiological Health, FDA conducts three principal activities:

(1) regulation—to establish performance standards for electronic products that emit radiation and programs to assure compliance by manufacturers and assemblers;

(2) research—to obtain knowledge necessary to develop standards and use-control programs; and

(3) education—to inform users how to use products safely.

To illustrate the magnitude of FDA's responsibility, Dr. Gardner mentioned that each year 13 million television receivers, 15,000 diagnostic X-ray systems, and 1.5 million microwave ovens are manufactured in compliance with the requirements of various FDA performance standards. Each of these products must bear a permanent label which certifies that it is in conformance with the applicable FDA safety standard.

Dr. Gardner submitted for the record a document entitled, "A Look at FDA's Program to Protect the American Consumer from Radiation." The document estimated that 270 million X-ray examinations will be performed in 1977, and 11 million microwave ovens would be in use in homes by 1980. One of the agency's major accomplishments has been the reduction of X-ray emissions from current TV receivers to levels that are too small to be measured. Other FDA programs assure the safe operation of 477 X-ray detection units used for screening hand-carried luggage at airports.

A document called "Highlights of Major Radiation Protection Activities" identifies a broad range of activities in FDA's electronic product radiation control program. About 60 percent of the listed activities involve either biological effects research or general research on measurement techniques and instrumentation. The other 40 percent are related to compliance, surveillance, and Federal/State relations.

In describing FDA's relationship to State radiological health programs, Dr. Gardner reported that FDA has contracts with 18 States to assure that newly installed X-ray diagnostic equipment complies with relevant standards. A combined Federal/State task force developed a system called NEXT (Nationwide Evaluation of X-ray Trends) which measures the effectiveness of State and Federal regulatory activities in reducing patient radiation exposure. The system, which has been adopted by 39 States and 7 Federal agencies, allows

participants to identify exposures that are excessive so that corrective actions can be initiated. A second program called DENT (the Dental Exposure Normalization Technique) is being used to monitor about 75,000 dental X-ray machines, constituting about two-thirds of those in the United States. According to Dr. Gardner, the participating States report an average 40-percent reduction in patient exposure to X-radiation.

On the subject of user control, Dr. Gardner described FDA's voluntary medical radiation recommendations. Guidelines under development include the use of X-rays during pregnancy, the use of routine chest examinations, quality assurance for X-ray facilities and other suggestions. In addition, FDA has approximately 1,500 multimedia training programs now in use to assist X-ray technologists in upgrading their capabilities. These programs are expected to reach some 20,000 of the estimated 75,000 credentialed X-ray machine operators each year. A Radiological Health Sciences Learning Laboratory has been designed and is now used by 49 medical schools for training medical school students, radiology residents, and practitioners. Dr. Gardner estimated that by 1980 all U.S. medical schools will have integrated this system into their overall medical education program.

Dr. Gardner described the research programs conducted by the FDA's Bureau of Radiological Health. These programs, which provide direct and indirect support for establishing regulatory standards and guidelines, are concentrating in the ionizing, microwave, medical ultrasound, and visible light areas. Acute exposure to ultrasound, for example, has been shown both to cause physical defects in rodents and to initiate blood clotting in the region of application. In addition, Dr. Gardner noted: "Acute exposure to microwaves of sufficient intensity can cause cataracts; some evidence now points to the possibility of cumulative damage from lower levels of exposure."

During the question and answer period, Dr. Gardner agreed with Senator Ford's suggestion that the risk of exposure to radiation for the population as a whole has increased because there are more radiation emitting products and because there are more diagnostic and therapeutic techniques available today. However, Dr. Gardner noted that this increased opportunity for exposure is balanced by the knowledge that modern equipment must meet standards which limit radiation to safe levels or, as in the case of medical radiation, by assurance that the benefits outweigh the risks.

In responding to a question from Senator Ford, Dr. John Villforth, Director of FDA's Bureau of Radiological Health, explained that BRH does not inspect old X-ray machines; the States are encouraged to do that. In the 18 States where new X-ray machines are inspected, 30 percent fail to pass their initial performance test. Corrections are then made to bring those machines into compliance. Dr. Villforth stated that the lack of funds within BRH is the principal obstacle to participation by the remaining 32 States in this equipment monitoring program.

Regarding X-ray technologists, Dr. Villforth observed: "With the exception of the few States that have licensing requirements, there is no training requirement for employment as an X-ray technologist." He estimated that there may be 40,000 to 50,000 operators of X-ray machines who have no formal training or certification.

Dr. Villforth also reported that BRH is conducting an epidemiological study of Navy veterans who worked with radar equipment, a major source of microwaves. The study, however, was not sufficiently far along to determine whether any real effects could be traced to radar exposure. In Dr. Villforth's view, we are years away from fully understanding whether all of the phenomena reported in the Eastern European scientific literature are factual.

Recalling Dr. Schiff's testimony on the biological effects of nonionizing radiation, Dr. Villforth agreed that microwaves can produce measureable biological effects such as increased body temperature or changing heart rhythms. He cautioned, however, that these biological effects are not necessarily deleterious. He also agreed that it would be desirable to examine the whole question of chronic occupational exposure to microwaves with a view to placing a time limit on the exposures allowed by the present 10 mW/cm^2 standard.

The jurisdictional dispute between EPA and BRH, relating to the responsibility of controlling medical exposure to ionizing radiation, was also discussed. A memorandum of understanding between the two agencies was signed on January 18, 1977, but has not fully resolved the problem. Dr. Gardner indicated that if a workable agreement could not be established by October of 1977, someone else would probably step in and settle it. He believes that FDA should have exclusive responsibility for those products which are produced and used in the medical and healing arts or in consumer and industrial applications where there is a question of radiation safety.[1]

One of the most important topics considered during these hearings related to the ordering of unnecessary X-rays, i.e., X-ray examinations which have no effect on patient care. Dr. Villforth called attention to reports in the literature which indicate that about one-third of all medical X-rays might be unnecessary. For example, in a January 12, 1976 article in Medical World News ("Defensive Medicine. How Much Diagnostic Overkill?") the President of Blue Shield of California estimated that between 30–40 percent of current X-rays have nothing to do with the patient's clinical requirements. In that same article, the American Academy of Pediatrics reported that in a survey of its membership half the respondents said they were ordering more X-rays as a result of problems associated with professional liability.

Various methods for reducing unnecessary X-ray exposures were discussed. Dr. Villforth described one program that BRH is funding at the University of Washington Hospital. Under this program, professionals from the hospital developed a list of criteria that would have to be met before skull X-rays were permitted in the emergency room. Dr. Villforth reported that the application of these criteria led to a 40-percent reduction in the number of skull X-rays administered with no detriment to the patients. He suggests that similar criteria be developed for chest X-rays, spinal X-rays, and other diagnostic procedures. Dr. Villforth considered this approach one of the most promising ways to reduce overall exposure of the U.S. population.

[1] On Jan. 26, 1978, the President approved for publication in the Federal Register of Feb. 1, 1978, recommendations that were issued jointly by EPA and HEW relating to the use of diagnostic X-rays in Federal facilities. While that specific jurisdictional issue now appears to be resolved, the responsibility for other medical uses of ionizing radiation have yet to be resolved.

In order to help avoid duplicate examinations, BRH has designed and is now testing a patient record card which indicates the date and type of examination received as well as the place where the X-ray film is stored. Dr. Villforth explained that it is not possible to record the dose administered as this cannot be measured adequately.

Dr. William Rowe, Deputy Assistant Administrator for Radiation Programs, Environmental Protection Agency, emphasized EPA's role as the focus of Federal guidance on radiation problems. Under the authority inherited from its predecessor, the Federal Radiation Council, EPA is to:

> Advise the President with respect to radiation matters, directly or indirectly affecting health, including guidance for all Federal agencies in the formulation of radiation standards, and in the establishment and execution of programs of cooperation with States.

Dr. Rowe gave three specific examples of the way in which EPA has exercised its broad authority over radiation protection activities in the United States. These include (*a*) the publication of an annual report on radiation protection activities, (*b*) the publication of a second annual report entitled "Radiological Quality of the Environment", and (*c*) the provision of funds to permit the National Academy of Sciences/National Research Council to review research on the health effects of ionizing radiation. Dr. Rowe stated that these activities give EPA a perspective which enables it to set generally applicable environmental standards.

EPA believes that any exposure to ionizing radiation has some detriment which is proportional to the dose received. Dr. Rowe considers medical X-rays to be one of the greatest sources of public exposure to ionizing radiation. In an effort to supplement BRH and State programs in this area, EPA issued a Federal Register notice of intent to set guides for the use of radiation generating equipment in Federal facilities. The Department of HEW, however, questions EPA's authority to act in this area.

Dr. Rowe listed several areas in which EPA has attempted to reduce radiation exposure:

(1) Guidance became final on July 9, 1971 for radiation exposure of uranium miners;

(2) Interpretation of Federal guidance regarding radiation exposures in caves or caverns which exist in our national park system;

(3) Protective action guides related to the accidental release of airborne radioactive materials;

(4) Standards for the content of radionuclides in drinking water; and

(5) Comments on Environmental Impact Statements related to the design and siting of individual nuclear reactor facilities.

EPA's present concerns include (1) assessing the need for Federal guidance in the area of environmental nonionizing radiation (Dr. Rowe suggested that his staff favors some type of guidance in this area); (2) developing Federal guidance for radiation exposure from land which is contaminated with transuranium radionuclides; (3) working with FDA to develop protective action guides for food or water which may have been contaminated by a radiation accident or

by fallout from nuclear weapons testing; (4) examining the standards for occupational exposure to ionizing radiation; (5) establishing criteria and standards for the disposal of high-level radioactive waste resulting from the chemical reprocessing of nuclear fuels; and (6) exploring ways to reduce exposure from naturally occurring radioactive materials, especially where this exposure has been technologically enhanced by man's activities. Dr. Rowe emphasized the pressing issue of radioactively contaminated land reclaimed from phosphate mining in Florida.

According to Dr. Rowe, EPA's future efforts will include work on the health and environmental effects of exposure to low-level radioactive waste as well as extra-high-voltage power transmission lines.

Following Dr. Rowe's oral statement, there was a discussion of the jurisdictional boundaries between NRC and EPA relative to nuclear powerplants. The discussion revealed that NRC's authority extends only to the fence line whereas EPA is concerned with any radiation that goes beyond the fence as a result of contaminated effluents or atmospheric release. EPA does not have a widespread monitoring network which would quickly identify problem areas. Instead, it collects general information on the background level of environmental radiation in order to identify long-term trends, such as a general increase that might result from the cumulative release from all sources of radioactive material. Local monitoring is done principally by the States, often with volunteer assistance. EPA asserted that quality assurance programs are used to maintain the adequacy of measurement provided in this system.

EPA has two programs to assess the need for a general-population exposure standard for nonionizing radiation. One of these programs is examining the effects which may be produced by long-term exposure to low-level nonionizing radiation. This includes an effort to reproduce some of the experiments that have been carried out in the Soviet Union and Eastern European nations; the overall program is funded at a level of $830,000. The second program uses a mobile laboratory equipped with sensitive monitoring devices to measure the levels of radiation present in various environments—urban, suburban and rural. Thus far, EPA has found the mean exposure for the general populations to be in the range of 0.01 to 0.02 microwatts per centimeter squared. Some individual exposures were found to be much higher, especially in high buildings near radio, TV, or microwave transmitters. Dr. Rowe testified that there was no major problem raising from the average ambient exposure to people, but that concern must be directed toward high-exposure areas. EPA believes that while these efforts will be helpful in defining the scope of the problem, additional research will be required. There is the continuing problem of extrapolating from experimental data on animals.

Dr. Rowe agreed to with Dr. Schiff that the present exposure standard for microwave radiation needs to be reevaluated; it lacks a time limit, and the 10 mW/cm^2 level may be too high. At this time, however, the effects of low level exposure to nonionizing radiation are poorly known; the effects of low-level electric fields are even more uncertain.

Dr. Daniel Cahill of EPA's Office of Research and Development indicated that the Soviet Union and the Eastern European studies on the effects of chronic exposure to low-level radiation have concluded that

microwave exposure not only causes heating of animal tissue, but produces other effects as well. He said that during the last 5 years, experiments conducted in this country under EPA, DOD and HEW sponsorship have corroborated some of these observations.

Discussions with Dr. Cahill and Dr. Rowe also concerned the extent to which the production of electricity through the combustion of coal may be discharging radioactive materials into the environment. EPA is currently evaluating the extent of this problem, which mainly involves coal from the Western States.

Mrs. Rose Kushner, the executive director of the Breast Cancer Advisory Center, identified breast cancer as the number one killer of women between the ages of 44 and 55 in the United States. Mrs. Kushner said that in an effort to detect the disease while it is still in an early and curable stage the American Cancer Society (ACS) and the National Cancer Institute (NCI) joined in 1973 to cosponsor 27 breast cancer detection demonstration projects. Their purpose was to conduct annual screenings of about 270,000 women age 35 and over in cities all over the United States. The demand for participation in the program jumped sharply in 1974 after Mrs. Ford and Mrs. Rockefeller underwent mastectomies. However, the flood of media coverage on the benefits of mammography ignored the conflict among scientists about the potential danger of exposing healthy breasts to a known cause of cancer, X-rays. Mrs. Kushner observed that opponents of routine screening by mammography were arguing that radiation may actually trigger new cancers and that the risks of mammography outweighed the benefits in large populations of women.

On the basis of studies conducted in 1975 and 1976, the ACS and the NCI restricted routine mammography in the detection centers to women over age 50. Only in the case of high risk were women under 50 to receive the X-ray examinations. Mrs. Kushner told the committee:

> Various "authorities" . . . have published lists of high risk indicators—including fear of cancer—that, if valid, would mean 80 percent of all American women are in danger of developing breast cancer. Since the national incidence rate is only 7 percent, this is patently absurd.

In addition, she testified that a report regarding the operation of the 27 cancer detection centers showed that even after the August 1976 guidelines had been issued, a high percentage of women under age 50 were still being screened routinely. This discovery led the NCI, without the support of the ACS, to issue new guidelines in May of 1977 limiting mammography of women under age 50 to those who had already had breast cancer or whose close relatives had had the disease. She concluded:

> The result of this controversy has been a reign of terror compounded by confusion . . . One of the grave dangers has been that women who are at high risk of developing breast cancer have refused mammography.

Mrs. Kushner told the committee that the NCI examination guidelines apply only to the 27 NCI–ACS detection centers. BRH estimates there are 5,000 to 6,000 other mammography machines in hospitals, clinics, and doctors' offices throughout the United States. She also stressed:

> While the NCI–ACS projects were staffed by certified technologists who were able to get good films with two exposures per breast, out in the real world women were often mammographed by X-ray technicians who had minimal training and

had passed no qualifying examinations. In these cases, more than the two exposures per breast were often required in order to have good enough images for a radiologist to interpret.

Mrs. Kushner also discussed a BRH study of medical facilities in Pennsylvania and the District of Columbia which showed that some mammography equipment was emitting as much as 10 times the amount of radiation recommended by mammography's supporters.

Mrs. Kushner was concerned that BRH cannot require radiologists to participate in BENT (Breast Exposure National Trends), its free mammography quality assurance program, and that it cannot exercise any control over the use of X-ray equipment. "Our watchdog has no teeth," she concluded.

It is up to the individual States to see to it that the equipment is checked periodically, that it is well-calibrated, does not leak, exposes all patients to the minimum quantity of radiation required for maximum resolution, and that the technologists using the equipment know what they are doing. Most States' regulations vary from awful to mediocre.

Mrs. Kushner was concerned about licensing radiation technologists. She pointed out that only 3 of the 54 jurisdictions (including the District of Columbia, Puerto Rico, Virgin Islands, and Guam) of the United States have licensure requirements. She asked, "Why are there not Federal laws requiring that all X-ray technologists pass qualifying examinations, repeated every 5 years or so * * *?"

Mrs. Kushner cited the false negative as an even greater danger than triggering a cancer that will appear in 15 or 20 years. Referring to a comparative study initially conducted by the Health Insurance Plan of Greater New York (HIP), Mrs. Kushner noted that 17 of the 44 cancers found by mammography were microscopic in situ cancers. She wondered if such cancers might normally be stopped or even destroyed by the body's immune system. "Of course", she said, "these 'lucky' women are cured and will not die of breast cancer. But they might have lost their breasts for nothing."

In concluding her statement, Mrs. Kushner reiterated her testimony concerning certification and use-control:

It is outrageous that the baker whose scales give us 14 ounces of bread instead of a full pound is penalized when the radiologist whose mammograph gives us overexposure to irradiation is not. It is outrageous that the beautician who shampoos, cuts and sets our hair must pass difficult qualifying examinations and be licensed when X-ray technicians are not required to do so.

In the discussion which followed her statement, Mrs. Kushner reported that different guidelines for X-ray exposure had been developed by EPA, BRH, NASA, and NCI. She wondered why better coordination could not be achieved. She also suggested that Medicare and Medicaid programs might provide a means to require inspection of X-ray equipment.

Dr. Lauriston S. Taylor, honorary president of the National Council on Radiation Protection and Measurements (NCRP), discussed two issues: (a) "the general misuse of the principle of maintaining radiation exposure levels 'as low as possible' (ALAP)" and (b) "the transfer of the responsibilities of the Federal Radiation Council, as established in 1959, to a single Federal agency (EPA) which must live and operate in parallel with many other Federal agencies having legitimate concerns with health and safety in the field of ionizing radiation."

The NCRP was established by Congress (Public Law 88-376) in 1964. It consists of 75 members elected for 6-year terms and eligible for reelection. Approximately 300 other scientists—physicians, engineers, and others—work with the NCRP's 60 various committees.

Dr. Taylor observed that the NCRP introduced the principle of maintaining radiation exposure ALAP in 1948. In addition to the existing system of basic permissible dose standards for radiation workers and for the general population, NCRP concluded that it was desirable, possible, and standard industrial practice to maintain working radiation levels in individual installations well below those which are regarded as basic and acceptable. This ALAP principle is not only regarded as a good safety practice, but also helps to avoid the possibility of excessive exposure. The responsibility for good radiation protection practice therefore falls upon the user for whom ALAP provides a degree of flexibility and the use of commonsense and judgment which apparently is not possible within any rigid regulatory structure. Thus, it is possible to adjust a variety of individual working conditions which contribute to the total exposure covered by the basic permissible dose standards.

As an example, Dr. Taylor referred to the low levels of radiation exposure proposed by EPA and NRC for light water-cooled reactors. He said that NCRP has no reason to question the particular levels that were recommended, but it does object to the issuance of these new control numbers under the guise of the ALAP principle. "Regardless of how they are described, and perhaps restricted to certain situations," he said, "these numbers nevertheless become identified as exposure 'standards'. The result of this is a complicated and almost meaningless matrix of standards, many of which are impractical or impossible directly to maintain. Moreover, the use of such numbers has a strong tendency to lull the consciousness of the radiation user into failing to meet the need to be continuously alert and responsible in radiation protection matters. Once such numbers have been generated and become 'official' it is politically impossible to raise them at some later time should circumstances indicate the need."

To deal with this misuse of the ALAP principle, the NCRP recommends:

(a) Adherence to the basic maximum permissible dose levels or dose limits established by the NCRP or the ICRP (International Commission of Radiological Protection) and contained in their most recent publications.

(b) As an alternative to that, have some government agency come right out, frankly and honestly, and change the standards on a justifiable biomedical and political basis.

(c) Use of the conventional, industrial procedure of working out radiation levels that are lower than the basic permissible limits but allowing some judgment in the degree to which lower working levels may be employed.

(d) Retention of the intended flexibility of the principle of maintaining radiation exposure levels as low as practicable.

(e) Stop hiding oppressive radiation control numbers under the subterfuge of ALAP or other new names or new definitions that may crop up.

(f) And finally, recognize a structure of basic radiation protection standards for workers and the population, noting that such a structure now exists and is in use the world over.

Dr. Taylor also expressed concern about the transfer of responsibilities from the Federal Radiation Council (FRC) to the EPA in 1970 under President Nixon's Reorganization Plan No. 3. In reviewing the history of FRC's establishment, Dr. Taylor pointed out that a 1959 study by Dr. Robert Cutler of the Bureau of Budget examined

and completely rejected the idea of assigning FRC's responsibilities to a single Federal agency. The FRC was composed of department heads who assigned their top radiation experts to a "working group" that met weekly to discuss technical details and to negotiate agreement among the several agencies. The recommendations of this working group were then ". . . modified or approved by the most senior officers in the Government with a stamp of authority that could not be achieved were the FRC in any single agency."

Dr. Taylor said he believed the intended jurisdiction of the FRC was discernible from the eight reports issued by that body. He complained that EPA's interpretation has "grossly overextended" its activities into such "improper areas" as medical and occupational exposure to ionizing radiation. Further, he indicated that EPA intends to extend its area of concern to nongovernmental medical practice by arguing that medicare services fall within the FRC scope of "Government needs."

In response to a question from Senator Stevenson, Dr. Taylor agreed that Government action at some level probably is required to assure adequate quality of X-ray technologists. However, the NCRP has not considered the question. He cautioned that regulatory procedures might introduce more problems than, for example, educational approaches. Dr. Taylor also agreed that X-ray equipment should be inspected periodically by State or local officials; he admitted that some States ". . . have relatively nonexistent programs, very meager programs, if any at all."

Dr. Taylor commented on the difference between the high levels of radiation that are used for therapeutic purposes and the much lower levels that are permitted for long-term exposure in occupational surroundings or for the general public. He explained that the permissible standards are inappropriate for therapy. "When you are talking about therapy," he said, "you are treating a disease and you are giving very large doses of radiation. And there can be very gross effects."

Regarding the difference between United States and Soviet standards for microwave exposure, Dr. Taylor said:

> . . . we are informed by the chairman of our Biological Effects Committee, who has just returned from the Soviet Union within the past few days, that they are now . . . talking themselves about adopting the same level that we are using now in the United States.

Dr. Taylor mentioned that an NCRP committee is examining radiation from consumer products such as smoke detectors, television sets, home furnaces, as well as medical X-ray exams—a total of about 30 sources.

Dr. Irwin Bross, director of biostatistics at Roswell Park Memorial Institute reported that during the preceding year there had been a major scientific breakthrough in our knowledge of the health hazards of ionizing radiation in the 1 rad range—that is, between about 0.1 rad and 20 rads. This range covers most of the current exposures to medical and nuclear radiation. Dr. Bross added, "There was some solid information 1 year ago that the 1-rad level was far from harmless, but this evidence was ignored or concealed by the guessing games and controversy that had gone on for so many years." Dr. Bross explained that the "guessing games" referred to the common use of the technique of linear extrapolation from animal data to effects on man.

According to Dr. Bross, "The hazards at 1 rad are far worse than anyone expected. They are much worse than the extrapolative estimates from the BEIR (Biological Effects of Ionizing Radiation) Report."

Referring to his own work and some confirmatory studies conducted by Drs. Mancuso, Stewart, and Kneale, Dr. Bross said:

> These major scientific achievements in the past year might seem to deserve a Nobel Prize, but, in point of fact, in both cases the reward was a cutoff in the funding of the research by angry radiation technologists at ERDA and angry radiologists at NCI.

He agreed to supply details to substantiate these accusations.

Dr. Bross estimates that about 10 million Americans receive unnecessary X-rays each year. He argued that these X-rays are ordered routinely because they will be paid for, also routinely, by third-party insurers. Dr. Bross cited an AMA survey which estimated that three out of four American physicians practice defensive medicine—ordering unnecessary laboratory tests or X-rays or both for the protection of the doctor in the event of a malpractice suit. Other reasons for unnecessary X-rays include ". . . sheer habit, the persistence of antiquated notions about annual examinations for T.B. and other diseases, and the inability of patients to get possession of their own X-rays when they change doctors". He said, "There are two things we need to do. First, a certificate of necessity signed by two physicians should be required before there can be any third-party payment for X-ray . . . The second requirement is that these certificates of necessity be monitored . . . Naturally, the doctors should have a hearing and appeal procedure in a quasi-judicial process." Dr. Bross estimated that such a monitoring system could be operated for a few million dollars per year and would save at least 10 times its cost.

In addition to his formal statement, Dr. Bross explained how low-level X-rays may be more damaging than previously suspected. He told the committee that X-rays cause cancer by breaking the delicate structure of human DNA. Over a period of years, these modified cells multiply billions of times before appearing as a visible cancer. The reason that higher radiation levels are very inefficient at producing cancer is that you cause and cure the cancer at the same time. In fact, when you treat cancer with radiation you give very high doses so that cell production is completely blocked. That is why when we extrapolate data from the radiation given at high levels to the radiation given at low levels on a per-rad basis, you can get much more cancer than you would expect from linear extrapolation.

In the use of X-rays, according to Dr. Bross, one should not take the risk of starting cancer unless the benefits clearly outweigh those risks. For example, in an urgent, life-threatening situation such as a fractured skull or a lump in the breast, Dr. Bross said that an X-ray would be justified. He would not, however, subject a perfectly healthy woman to mammography.

Dr. John Osepchuk, of the Raytheon Research Division represented the Institute of Electrical and Electronics Engineers' Committee on Man and Radiation (COMAR). The IEEE established COMAR in 1972 in order to present the public and legislators with factual information on the biological effects of nonionizing electromagnetic radiation. COMAR's membership includes 14 scientists and engineers working to apply bioeffect research data to the development of safety

standards for human exposure to nonionizing radiation. The group also includes two representatives of the medical and life sciences.

Dr. Osepchuk testified, "Mass media coverage of this subject has continued to exhibit serious misinformation and flagrant embellishments of the truth that tend to highly exaggerate the degree and nature of hazards of nonionizing radiation." He believes, "A failure of responsible groups and individuals to rebut this false picture could lead to serious harm in our society including:

(a) Deprivation or delay of beneficial applications of electromagnetic technology;

(b) Unnecessary fears of citizens and consumers of electricity;

(c) Depressed activity in technical industries;

(d) Additional costs to consumers; and

(e) Additional costs to citizens."

Dr. Osepchuk provided a short tutorial review of microwave radiation including the observation that for any object with electrical properties similar to biological tissue, there is a frequency range (roughly centered where free-space wavelength is of the order of the body dimensions) for which maximum total absorption occurs and "hot spots" can develop. At very low frequencies the body acts like a conductor and shunts out the electric field. At very high frequencies the radiation behaves optically and is absorbed near the surface of the body. Dr. Osepchuk illustrated the implications of this information by demonstrating that microwave radiation of a given frequency will have very different effects on a fruit fly, a mouse and an elephant simply because of their different sizes; one must therefore be careful about extrapolating animal data to man.

Dr. Osepchuk provided a graph which compared various U.S. microwave exposure standards with those of the U.S.S.R. The graph indicated that permissible exposures in the U.S.S.R. are lower and are reduced as the duration of the exposure is increased.

Dr. Osepchuk emphasized the difference between a standard which restricts the amount of radiation emitted by a device and one which limits the exposure of personnel to that radiation at some appreciable distance. In regard to personnel exposure he said:

> The U.S. standard has a safety factor of at least 10. It protects against potentially irreversible damage. The Soviet standard has a safety factor of 100 and protects against reversible functional disturbances believed to occur per chronic exposure. However, the Soviet standard for microwave exposure remains at the same constant level of 10 microwatts/cm^2 for all exposures in excess of about 2 hours. This suggests that the U.S.S.R. does not consider microwave doses to be cumulative; otherwise they would keep reducing the permissible level as exposure periods were increased.

Dr. Osepchuk believes that there are real thresholds for damage by nonionizing radiation and that there can be no truly cumulative effects from long-term exposure as might occur from living or working near broadcasting services.

In contrast to the wide differences in exposure standards, Dr. Osepchuk pointed out that the United States and the U.S.S.R. have the same emission standards for microwave ovens. He believes that arguments for "zero leakage" are absurd and argues, "People fear that microwave radiation at any low level could be potentially dangerous. This is science fiction. If we were to say that, you might as well shut down broadcasting and everything that emits anything."

On the subject of microwave radiation beamed at the U.S. Embassy in Moscow Dr. Osepchuk concluded, "There appears no basis for the fearful speculations in the press." He added:

> The official denial by the State Department of a relation of the radiation to personnel health problems appears valid. COMAR believes, however, that a more forthright description of the radiation by the State Department would serve to produce a more satisfying rebuttal of the speculative fears.

COMAR believes that the potential for pacemaker interference by modern microwave ovens is "essentially nil." It is regarded as a pacemaker susceptibility problem rather than a radiation hazard and soon will be controlled by FDA regulations. Proposed emission standards for microwave diathermy applicators are also opposed as unnecessary.

Dr. Osepchuk told the committee that COMAR had recently responded to two articles on microwave radiation which were written by Paul Brodeur and appeared in *New Yorker* magazine. According to Dr. Osepchuk, Mr. Brodeur,

> . . . implied that the military, Government, industry and the scientific community were engaged in covering up serious potential hazards of nonionizing radiation and that serious potential hazards to the general population existed from such radiation. COMAR found Brodeur's thesis unfounded and the publication of his articles a disservice to the general public.

Dr. Osepchuk assured the committee that COMAR "strongly supports further research on the bioeffects of nonionizing radiation. There is no crisis," he said, "no imminent health hazard from low-level nonionizing radiation." However, because electromagnetic technology pervades modern society, it should be self-evident that potential side effects and interaction with biological organisms should be investigated.

Dr. Osepchuk described the distribution of research effort over the electromagnetic frequency spectrum from about 300 Hz to 300 GHz, most of it concerned with animals. He suggested more research on frequency dependence and in relating animal data to effects of man. He also urged more research on millimeter waves and in the use of microwave heating for cancer therapy and general heating.

Dr. Osepchuk cited the need for better public education in the nature, benefits, and potential hazards of electromagnetic energy. The public needs to understand that:

(a) Electromagnetic energy associated with the spectrum from ordinary electricity to visible light is nonionizing and is not equivalent to the "radiation" associated with X-rays or nuclear systems which display the potential for cumulative and more insidious effects;

(b) Nonionizing electromagnetic energy has been in use in many areas of modern society for many years without serious human injury due to radiation effects;

(c) Not all biological effects are hazardous;

(d) Beneficial uses of electromagnetic energy range from household electricity to broadcasting or medical applications; and

(e) Sufficient understanding of the effects of electromagnetic energy to protect against known thermal hazards has been available for years. In order to improve public education along these lines, Dr. Osepchuk suggested that Government agencies sponsor educational material for use on radio and television as well as in the printed media.

In conclusion Dr. Osepchuk quoted from a paper by Don Justesen:

> The assumption of hazardous nonthermal effects at low densities of radiation, which are suspected by some but are as yet unsubstantiated by anyone, is a fabrication from the whole cloth of fear. This fear, which feeds on the absence of verified or verifiable evidence, is hampering basic studies and may thereby restrict medical development and application of radio-frequency radiations.

Senator Stevenson asked if any deleterious side effects were produced by microwave diathermy treatment. Dr. Osepchuk reminded the committee of some testimony presented in 1973 by Professor Lehman of the University of Washington. According to Dr. Osepchuk it was Professor Lehman's view, and the view of his profession, that there had been no deleterious effects to patients undergoing the modality when treated by competent professionals. He also described an extensive followup investigation which revealed no cataracts in patients who had received diathermy treatments to the eye.

Studies conducted by Dr. Russell Carpenter on the microwave exposure of rabbits indicate a cumulative effect in producing cataracts; however Dr. Osepchuk believes that these experiments were conducted at power levels very near to the thresholds for producing cataracts. While the first exposure might not be effective, the fifth or sixth exposure would. At lower levels, however, such 10 mW/cm^2 (rather than the 75 or 150 mW/cm^2 which did produce cataracts), Dr. Osepchuk said that Dr. Carpenter's experiments produced no cataracts after months of exposure. He claims that negative results were also found in similar tests by Dr. Guy at the University of Washington.

Dr. Russell H. Morgan testified on behalf of the 14,000 physician and physicist members of the American College of Radiology (ACR). Dr. Morgan opened his testimony by presenting ACR's opinion that the Nation's public and private controls and guidelines for medical and other uses of ionizing radiation are "in relatively good order and working well." However, he said, "There are no absolutes. Problems remain in both the private and public sectors. But taken on the whole, Americans are not being subjected to grossly improper radiation practices or excessive levels of exposure."

Dr. Morgan listed 3 areas of concern for radiologists and others working with medical radiation. These were:

1. The absence of a focus for radiation-related research within the Federal Government.
2. An overlapping and sometimes contradictory pattern of regulatory efforts by Federal and State agencies in the health field and elsewhere in the Government.
3. An emphasis on health cost containment which seems likely to stifle further development in radiation equipment.

Dr. Morgan told the committee that medical radiation accounts for more than 90 percent of all manmade ionizing radiation received by Americans. Perhaps three of every five Americans receives an X-ray examination in any year. He noted, "The contribution of this medical radiation to the absorbed radiation received by the population as a whole is about the same as that received from natural sources. Of course," he admitted, "certain individuals receive much more, particularly those receiving radiation treatment for cancers." In those cases lethal doses of 5,000 to 7,000 rads are delivered to the tumorous tissues to destroy them. Of course, effort is made to deliver lethal radia-

tion to the entire tumor and to spare surrounding tissues to the greatest possible extent.

Dr. Morgan pointed out:

> Most medical X-ray examinations contribute less than one rad—1,000 millirads—or 12 times annual background radiation, to the body part being studied. A few may contribute two or three rads. At those levels, there have not been any directly observable biological effects. However, we know that there are biologically harmful effects from X-ray exposures at higher levels. Certainly we can observe effects at 100 rads and some types of effects at only 25 rads in a large enough study group. Below that, we must resort to indirect methods of observation using epidemiological and statistical methods.

Dr. Morgan described the linear nonthreshold extrapolation technique for estimating the effects of low level radiation as a "worst case theory" which almost certainly overstates the impact of low-level ionizing radiation and which is capable neither of absolute proof or absolute refutation. He also pointed out that the National Council for Radiation Protection and Measurements has cautioned against the literal application of this technique to public policy issues involving radiation exposure. According to Dr. Morgan, this technique assumes that the body has no recuperative factor from radiation injury. He added, "We know that such an assumption is not correct in any literal sense."

Dr. Morgan discussed the potential for genetic effects and described the animal and epidemiological experiments used to study radiation-induced genetic effects. All mutations induced by exposure to ionizing radiation are assumed to be deleterious, and radiologists are especially careful about medical exposures of reproductive organs, particularly in women of childbearing age. "We know," he said, "that radiation may have an effect upon genetic materials at doses which show no effect upon the person receiving the exposure."

In spite of these uncertainties, Dr. Morgan concludes:

> The tradeoff of medical radiation benefits against risks can be seen to be generally favorable. If a properly selected X-ray examination is properly performed, the diagnostic information greatly outweighs the theoretical or statistical risk. This is true even when the patient may have a special circumstance, such as pregnancy, if the clinical question raised by her physician is not answerable by other diagnostic methods.

ACR supported enactment of the Radiation Control for Health and Safety Act of 1968 and believes:

> There is a proper role for Government in the safe and effective medical uses of X-rays. But that role is not simply a regulatory one. Equipment can be regulated. Medical judgment cannot be . . . Presently, we are distressed to be the target of a rousing bureaucratic battle among Federal agencies who would regulate us in various ways.

Dr. Morgan also commented on the jurisdictional dispute between HEW and EPA. He feels that HEW did little to exert management control over its own radiation-related programs until EPA claimed a domain over medical radiation on the basis of the responsibility inherited from the Federal Radiation Council. However, Dr. Morgan believes:

> The eight FRC reports which set National policy in the 1960's all avoided positions on medical radiation. In addition, it seems to us that Reorganization Order 3, which created EPA, specifically left medical radiation to HEW and retained the major portion of the Bureau of Radiological Health within HEW to carry out Federal responsibilities.

Dr. Morgan believes that legislatively established maximum radiation doses restrict the freedom of a physician to pursue the diagnosis of a particular problem. He was also concerned for the patient whose problems had still not been resolved even after the maximum doses had been administered.

In responding to the earlier statements of Dr. Bross, Dr. Morgan submitted for the record a paper by P. G. Smith, M. C. Pike, and L. D. Hamilton, which, he claims, ". . . raises serious questions about some of the premises and assumptions which Dr. Bross has made." In summarizing his remarks to Dr. Bross' statement, Dr. Morgan believes, "Nothing has changed as far as our understanding of the relationship between dose and biological effects."

Dr. Morgan thinks that the States are doing a "rather spotty" job of assuring proper maintenance of X-ray equipment. In most of the large hospitals, however, there are knowledgeable staffs of physicists who are continually on the lookout for maintenance problems.

Dr. Morgan pointed to organized efforts to insure that more technologists are well-trained. These include an AMA review of X-ray technician training programs and administration of periodic examinations by the American Society of Radiological Technologists. Dr. Morgan states that 107,000 X-ray technologists had passed the ASRT exams but estimated that 70,000 more practicing technicians had not. Dr. Morgan was not sure whether any regulatory action was required.

Dr. Herbert Pollack, an independent consultant to the State Department's Office of Medical Services, cautioned the committee that he would be presenting his own personal account of the microwave radiation at the Moscow Embassy and that his views were not necessarily those of the State Department.

Dr. Pollack traced the history of the Moscow signal which may have existed as early as 1953, but was not verified until the early 1960's. In 1963, a recorder began to monitor the signal 24 hours a day. The maximum radiation level was 5 microwatts/cm^2. To receive maximum exposure, a person would have had to stand at an open window in the strongest part of the beam during the entire time of transmission. Clearly, no one had maximum exposure.

State Department officials investigated possible health effects from microwave exposure. After reviewing the scientific literature on the bioeffects of microwave radiation and the health records of Embassy employees, consultant medical experts, including Dr. Pollack, assured the Department of safety. The Embassy personnel were not informed because no known health effects were involved.

In order to determine whether this radiation could cause any behavioral effects, DOD in 1965 initiated Project Pandora (classified), which exposed monkeys to a synthetic signal much stronger than that encountered by Embassy employees. In spite of some early positive indications reported by one of the participating scientists, the Pandora Review Committee concluded that there were no observable behavioral effects. Project Pandora was originally classified by DOD ostensibly to avoid alarming Moscow personnel who had not been briefed about the presence of the signal. Pandora has since been declassified.

The original signal, from the east side of the Embassy, continued until May 1975. A similar signal was detected from the west between January and March 1973 and briefly on February 1, 1974. On May 28, 1975, the newer signal was detected again. A third signal from the

south began in August 1975. Continuous monitoring of the latter two signals showed radiation levels as high as 18 microwatts/cm ^{2}, pulsing of the signals, and gradual increase of activity from 10 to 18 or 20 hours a day. This combination of circumstances caused a reassessment of the situation at that time.

A complete review of the medical records of the staff and dependents in December 1975 again disclosed only the usual health problems of a small population. Because radiation intensity was increasing, and it was unknown how high it might go, a decision was made to install screening on the Embassy for protection. Officers and staff were briefed at that time to explain the purpose of the screening and to alleviate any possible anxiety. Formal protests were made to the Soviet Government because radiation occasionally exceeded the Soviet occupational standards of 10 microwatts/cm^2—although the U.S. standard is 1,000 times higher.

In view of continuing employee concerns, the Department of State decided in March of 1976 to support an epidemiological study of Moscow Embassy staff and dependents since 1953, compared to cohorts from other Eastern European Embassies. Conducted by the Johns Hopkins University School of Public Health, the study should disclose any differences in the health or longevity of the groups and may differentiate radiation effects from other environmental factors.

Additionally, serial blood counts have been conducted on Moscow staff and dependents since February 1976. These have been compared to the blood counts of several hundred Foreign Service personnel returning to Washington from other posts. One-third of the Moscow subjects have demonstrated "a benign, mildly elevated lymphocyte count." The incidence of elevated lymphocyte counts, however, was not correlated with the degree of potential microwave exposure. Other possible causes for the anomaly were being examined, but at the time of the hearing, no explanation had yet been found. No medical ill-effects had been observed in the affected one-third, and the condition disappeared after departure from Moscow.

Dr. Pollack's final remarks on the Moscow situation concerned four different children of Moscow Embassy employees who were carefully examined by a variety of medical groups in the United States due to a concern over their raised lymphocyte levels. In three of these cases, no problems at all were found. The fourth had an elevated lymphocyte count due to a congenital defect in the bone marrow.

Dr. Pollack was unable to explain the purpose of the Soviet irradiation of the U.S. Embassy in Moscow. He did say, however, that he would stake his professional reputation on his opinion that "no physical health effects have been demonstrated to date."

Dr. Pollack then changed to another topic—current knowledge of and research on the effects of nonionizing radiation. Regarding the great differences between Eastern and Western safety standards, he made two points:

1. We have studied Soviet research reports, but have been unable to duplicate experiments to verify their results; and
2. Soviet military forces are not bound by their safety standards, but U.S. forces must comply with our standards.

Current U.S. research was described as a two-pronged effort—the theoretical and experimental search for mechanisms and the pragmatic study of effects on animals and man.

The development of methodology and instrumentation for measuring absorbed energy as opposed to incident radiation was credited with opening new vistas in the laboratory. Dr. Pollack feels this approach may afford:

(*a*) A method of finding the mechanism of interaction;
(*b*) A method of translating findings from animals to man;
(*c*) A means of relating external to internal fields; and
(*d*) A means of relating a known amount of absorbed energy to an observed response.

Epidemiology is an important field of research which Dr. Pollack feels has not been adequately explored. The problems, however, are enormous. First, there is the question—what health effects to look for? Even more difficult is the problem of defining the exposure levels of people and identifying potential groups for study. Dr. Pollack wonders how one can account for the multitude of environmental factors such as air or water quality which might influence results. Instrumentation problems were also cited.

Dr. Pollack sees many drawbacks to the concept of a single agency responsible for research and regulation of all radiation. Research under such an agency could suffer from a lack of flexibility and innovation which are badly needed in this field.

Dr. Pollack described some of the problems of experimenting with nonionizing radiation on live animals and stressed the importance of building multidisciplinary teams. High priorities for research should include pragmatic studies of chronic low-level exposure, the impact of peak powers, and epidemiological studies. Theoretical and experimental studies must probe all the mechanisms of interaction between electromagnetic fields and living systems.

Dr. Pollack believes the current mechanism for coordinating research on the biological effects of nonionizing radiation is working successfully and should not be disrupted. The effectiveness of this coordination is largely due to the open, supportive, and noncompetitive role of an office at the level of the Executive Office of the President, and the dedicated efforts of the personnel on this task.

In summary, Dr. Pollack concluded:

> There is no present crisis of environmental pollution insofar as health is concerned from this modality. Any necessary regulatory action must be based on research findings and demonstrated need. It is important that we do not stifle this emerging field by administrative controls set in the concrete of a rigid bureaucracy. You have inferred the urgent need for answers to the question of hazards. The most effective way of speeding up the research program is to create a climate which will attract scientists into the field, and then support their work.

He later added, "Standards must be set based upon experimental work and demonstrated needs. At the present time, there is no demonstrated need for the change...."

A panel of four individuals presented testimony on behalf of the Department of Defense. An informal discussion was conducted after all four had completed their statements.

Capt. Frank H. Austin, Jr., MC, USN, Assistant Director, Environmental and Life Sciences Office of the Director of Defense Research and Engineering began by summarizing DOD's formal response to questions submitted by this committee prior to the hearings. In DOD's opinion:

(*a*) There is a high degree of cooperative interdependency between DOD and other Federal agencies. Representatives meet frequently to exchange scientific and technical data.

(*b*) There are no significant problems affecting DOD which result from confusion among State and Federal radiation-related responsibilities.

(*c*) A clear definition of the jurisdiction of each Federal agency would help to prevent confusion in the future when new nonionizing radiation standards are proposed.

(*d*) The military services have generally proposed adequate funding for execution of the Tri-Service EMR Research Plan. Budget realinements within DOD may result in some program extensions of the research plan.

(*e*) Removing biomedical research from DOD for consolidation within a single Federal agency would be detrimental to the timely development of weapons systems and is not supported.

Captain Austin indicated that the Tri-Service Electromagnetic Radiation (EMR) bioeffects research plan was prepared in June of 1975 and has been reviewed and updated each year. The program's principal objective is no maximize personnel safety while maintaining operational readiness. Captain Austin indicated that the program will be organized to answer logical questions in a priority sequence, and many isolated reports of so-called low-level bioeffects may not be immediately addressed by DOD researchers. "On the other hand," he said, "the program will provide the best available collective data base of EMR bioeffects to make timely and appropriate decisions in support of specific DOD systems operations."

Captain Austin noted:

The nonionizing electromagnetic radiation area is a large, complex, multiparametered problem that has captured the interest of consumer protection groups, environmentalists, regulatory agencies, legislators, and scientists from around the world. There is National and international concern about the presently accepted "safe" level.

The DOD is the Nation's largest user of nonionizing electromagnetic radiation devices, including a wide variety of reconnaissance, surveillance, and communications systems in air, sea, and ground operations.

The majority of these devices have:

Service or system specific parameters, that is frequency, power, pulse rate, pulse width, and mode of operation. These variables all contribute somewhat differently to the potential biological injury problem, so human hazard assessments require multiple parameter studies.

Captain Austin concluded:

DOD's responsibilities as a major user of the EMR spectrum encompass safety criteria from design through production to operational employment. Legislation on environmental protection, occupational safety and health, and concern for general population safety necessitate a strong service specific R&D program to support military systems development and operational applications while assuring the protection of the EMR system operator and the general public.

He added:

The scientific evidence available today is inconclusive to support changing the EMR standard either upward or downward. The ultimate goal of our research is to make this determination.

Maj. Lawrence E. Larsen, MC, USA, Chief, Biophysics, Department of Microwave Research, Walter Reed Army Institute of Re-

search, displayed a chart showing the number of Army transmitters and transceivers used in each of 13 different regions of the electromagnetic spectrum from 3 kHz to 40 GHz. Nearly 350,000 transmitters were accounted for. Major Larsen indicated the necessity of doing research over a broad range of frequencies. A second chart showed the geographical location of high-power radar units within the United States. Approximately one-half are in New Mexico.

Major Larsen listed five different characteristics of radiation which must be determined if one is to assess the physiological-medical effects of these emitters. They include power, frequency, duration, modulation, and geometry. Similarly, one must know the geometry of the biosystem, its energy absorbing capabilities, what fields are induced in the body by the incident radiation, what happens to its temperature, which of its organs, tissues, cells, and molecules respond to the field, and how they are affected by it. Additional charts showed that different frequencies will couple with different parts of the body simply because of their matching sizes.

Major Larsen described the major elements of the Army's management strategy relative to radio-frequency radiation—(1) identification of biological effects with analysis of such parameters as frequency, power, pulse rate, et cetera; (2) identification of the biological mechanisms involved in order to develop a predictive capability; and (3) determination of any medical hazards. After giving details of the research program's organization, he listed a number of its major accomplishments. For example, the program has developed methods for continuously measuring temperature changes in the organs of animal subjects during radiation exposure, established the feasibility of using nonsurgical methods to measure the microwave energy deposited in nonliving targets, and demonstrated that microwaves can affect such basic biological properties as cell growth rates and metabolism. The program has also identified the unique hazards of exposure to pulsed microwave radiation as compared to continuous waves, identified some behavioral effects of microwave irradiation, and demonstrated the antenna-like properties of animals or their organs for specific microwave frequencies. The Army has found no unique association between occupational microwave exposure and the formation of cataracts.

Major Larsen concluded by directing the committee's attention to "The emerging technology of potentially beneficial diagnostic and medical applications of microwaves."

Capt. Paul E. Tyler, MC, USN, Director, EMR Project Office, Naval Medical R. & D. Command, told the committee that the Tri-Service program of research on effects of nonionizing radiation "is probably by far the best coordinated research program within the Federal Government at the present time." The Navy's major efforts are in microwaves and extremely low-frequency; (ELF) electromagnetic signals.

According to Captain Tyler the Navy has conducted over 45 separate biological/ecological research projects in the ELF area. These projects have covered such subjects as physiology, biochemistry, behavior, growth and development, biological rhythms, human performance, genetics, and ecology. Captain Tyler noted that an interim report issued by the National Academy of Sciences in December of 1976 concluded, "There did not appear to be any cause for concern that

this (the Navy's) ELF system would adversely affect humans or the environment."

The goal of the Navy's microwave program is the development of criteria for use in the establishment of standards, limitations, and design guidelines to protect naval personnel and the general public. Since each of the many parameters involved in any discussion of microwave effects can take on so many different values, Captain Tyler remarked:

> It is easy to see why nonionizing electromagnetic radiation is far more complex than ionizing radiation. To complicate matters even further, the various portions of the spectrum require different radiating and exposure facilities.

Captain Tyler listed five principal areas of Navy effort: 1. central nervous system; 2. behavior; 3. immunology/hematology; 4. occular effects; and 5. dosimetry and energy distributions.

Alterations in the permeability of the blood-brain barrier had been noted using three different techniques in small animals, but no thresholds have yet been established.

Captain Tyler noted that reports linking microwaves with several disease processes, particularly cataracts and heart disease, are case reports and in no way provide any scientific evidence as to a cause-and-effect relationship. To this date, laboratory studies have indicated that substantial thermal levels must be reached before cataracts can be produced. Even in animals such as the rabbit, this requires an excess of 100 milliwatts per centimeter squared—an exposure that is high enough to kill the animal, unless the rest of his body is shielded.

Mr. John C. Mitchell, Chief, Radiation Physics, Radiation Sciences Division, U.S. Air Force School of Aerospace Medicine, listed as one of the Air Force's major contributions and continuing programs:

> . . . a series of studies to describe how radio-frequency radiation is distributed in biological organisms. These studies show conclusively that the effect of RF radiation on biological systems is dependent not only on the magnitude of the exposure level, but also on the frequency of the radiated energy as well as the size and orientation of the organisms in relation to the emitter.

Mr. Mitchell noted: "While much knowledge has been accumulated, the biological consequences of RF radiation exposure are still sufficiently complex that the real-world impact on man's state of health may not be known for several years." In order to develop a necessary link between biological effects observed in animals and the corresponding effects which could occur in man, the Air Force has undertaken a multiyear program to develop and update a radio-frequency radiation dosimetry handbook for use by all investigators. The first edition was issued in September 1976; an updated version was released in May 1978.

Since RF radiation-induced effects are frequency dependent, the Air Force believes that safety criteria should vary with frequency. The Air Force developed and published its current regulation in November of 1975. From 10 MHz to 10 GHz, the Air Force standard is consistent with OSHA's. However, for the lower frequency region from 10 kHz to 10 MHz, where no previous standard existed, the Air Force—based upon lower relative power absorption—allows slightly higher exposure.

Mr. Mitchell presented a chart which compared the Air Force exposure standard to other actual and proposed standards and pointed out, "It is important to note that the U.S.S.R. applies frequency-dependent modifiers to increase their permissible exposure levels below 50 MHz." He continued, "Future standards must be based on the results of well defined, replicated studies that clearly demonstrate that the effects (of

RFR) are detrimental to human health or performance, and that they do not represent transient or inconsequential phenomena from which there is always complete recovery."

During the discussion period which followed the formal presentation by members of this panel, Senator Ford asked why Project Pandora was classified. None of the panel members was able to answer. Major Larsen, who was present as the project was winding down, suggested that the Advanced Research Projects Agency, which conducted the project, might be able to provide an answer. He estimated that the project utilized about $2.5 million for facilities and $200,000 to $300,000 for contracts. While he did not know exactly what happened to the original data, he had witnessed its removal from the building.

Senator Ford asked what potential health hazards might be associated with the development of weapons systems that emit electromagnetic radiation. Captain Austin answered, "All of the research that we are doing is looking for some sort of bioeffects." He specifically mentioned cataracts and other effects that might result from microwave heating. Captain Austin told the committee he was not aware of any classified research in this area now being conducted by DOD. He believes that the present U.S. standard for exposure to radio-frequency radiation is adequate and sees no reason to suggest changing it up or down. A Canadian proposal to adopt a standard at the 1 mW/cm^2 level was also discussed. Captain Tyler reported that the Canadian members of the NATO Committee, which is considering such a change, ". . . are still in concurrence that a 10 milliwatt standard is safe at the present time." He indicated that other persons in Canada do have other opinions. Mr. Mitchell spoke of several other proposals which have been considered in Canada.

Captain Tyler, when asked to comment on the degree of overlap between the various research efforts said, "I really don't think there is overlap." He pointed to the large number of frequencies and other parameters to be explored. He also felt that a certain amount of duplication by separate researchers is desirable to eliminate bias and to facilitate variations in experimental approach. He believes that if an investigator reports a particular finding, it is desirable to have that confirmed by different investigators in different laboratories. Captain Tyler cited the permeability of the blood-brain barrier as a classic example of using entirely different experimental approaches to verify one observation.

Regarding the possible transfer of OTP's ERMAC from the White House, Captain Tyler said that it would have no impact within the tri-service program. However, he thinks:

> It will make it more difficult for the various agencies to keep as close a working relationship as we have at the present time. The coordination function must be above the individual agency level.

Captain Austin was unwilling to speculate about why the Russians would want to irradiate the U.S. Embassy in Moscow with microwaves.

Senator Ford asked Major Larson to speculate on radio-frequency radiation's possible physiological effects on man. Major Larsen explained that Polish research has suggested that certain forms of radiation cause guards to have seizures and things of that sort. However, "We have not been able to confirm those findings," he said. In fact, the Army's research with animals, which already have a propensity for

seizures, found that microwave exposure has only a transient effect on seizure susceptibility. This transient effect is one of decreasing threshold, but with continued exposure, the effect goes away." Mr. Larsen also outlined the Army's plans for studying radiation-induced changes in the permeability of membranes, for example, the blood-brain barrier.

Senator Ford noted that Major Larsen's prepared statement mentioned that nonliving objects can emit sound when they are subjected to pulsed microwaves, that humans are reported to have heard microwaves and that Eastern European nations have experimented with animals susceptible to fits. He wondered if these observations might imply that the Eastern European research on microwaves is directed toward altering nervous system functions from a military weapon's point of view. Major Larsen answered that he was a physician and was not privy to information on weapons development. He suggested that Senator Ford talk to the Army's Development and Readiness Commander. He added, that on the basis of information available to members of the panel, ". . . the United States is not developing any directed energy microwave weapons."

Responding to another question, Major Larsen speculated:

> . . . human beings might find certain microwave environments to be unpleasant in ways that are rather vague. The conditioned aversion experiment we described in the testimony is a sensitive behavioral test for properties of radiation, whether ionizing or nonionizing, where the exact mechanism of action is unknown (or widely diffused).

In an attempt to be more specific he said:

> I think an analogy might be, for example, office workers who find that they are particularly tired after spending time in offices that have lots of subsonic sounds. It is not something that you would directly perceive, but it is something that would affect your perception of pleasantness or the unpleasantness of the environment.

Major Larsen reported that over a very wide range of exposure values, the Army's retrospective study has found no significant correlation between occupational microwave exposure and cataracts. Unfortunately, only estimates of exposure can be made as there are no personal dosimeters for recording microwave exposure. He feels there is a major point of disagreement with Dr. Milton Zaret on this issue. Major Larsen told the committee that the Army's Chief of Ophthalmology at Walter Reed feels there is no such thing as a microwave cataract. He would not argue about whether a given individual does or does not have a cataract, but he would question whether any such cataracts had been caused by microwaves rather than by some other disease such as diabetes; he would want to know if there might be a history of previous ocular trauma or hypertension, et cetera.

Captain Tyler was asked to identify some of the "rather adverse and subtle effects associated with particular types of extremely low-frequency exposure" that had been mentioned in his prepared statement and to explain why these effects would not present hazards if Project Seafarer were to be implemented. He responded, one effect:

> * * * has been alteration in the calcium binding parameters of the membranes of the brain. This starts to take place at about 56 volts per meter. At 45, 60, and 76 hertz, the Seafarer field is 0.07 volts per meter. They have found no alterations in the calcium binding below about 56 volts per meter at Seafarer frequencies.

Another effect that has been shown is some modification of growth parameters of slime mold, which is a primitive single cell organism. Again, this takes place at power levels two to three times the order of Project Seafarer; at the Seafarer levels, there are no changes in effects.

The one area we are still investigating is reported effects on bird migration. In talking to many of the experts in ornithology and bird migration, they even notice effects when migrating birds pass over large populated areas, particularly well-lighted areas.

We have noted from the Wisconsin test facility that as the field is being turned on or turned off, there appears to be some slight deviation in the bird's course [as observed] by radar tracking. Again, this really hasn't been confirmed yet. We are planning additional studies this fall. There did not seem to be any changes in the birds' migrating patterns when the Seafarer field was on in the steady state.

The final topic of discussion involved two cases of pancreatic cancer which had developed among personnel who had at one time been working with TACAN radar equipment in Rhode Island. Captain Tyler stated that the Navy did a quick survey in the spring of 1977 of all TACAN operators and equipment. It found no other personnel suffering from pancreatic or other cancers, almost zero microwave irradiation from the equipment under the test conditions, and no ionizing radiation. Captain Tyler called attention to some data from the National Cancer Institute which showed an unusually high incidence of pancreatic cancer in the States around Rhode Island. He concluded, "We think at the present time, it may be due strictly to the geographic area of these personnel . . . I think it is kind of an inexplicable incidence that these two people working at the same place at the same time showed up with cancer. As with many other disease States, anomalies do happen."

Mr. Guenther Baumgart, president, Association of Home Appliance Manufacturers, told the committee that while there have been three revisions of the Bureau of Radiological Health standard for microwave ovens since it first took effect in 1971, ". . . the permissible emission levels have not changed . . . It is the best judgment of experts in the field that they don't need change." Mr. Baumgart underscored three points from the earlier presentation by Dr. John Osepchuk:

1. Despite allegations to the contrary, microwave ovens which conform with BRH emission standards meet or are below Russian exposure standards. U.S. standards are also more conservative than Polish, Czech, or International Electrotechnical Commission standards.

2. The BRH standards are 10,000 times below levels known to produce harmful effects, according to the American Medical Association's Committee on Occupational Toxicology.

3. With millions of ovens in use there is not one single injury on record from microwave oven emissions. And many of these ovens have been in use since the 1950's, well before the Federal standards came into being.

Mr. Baumgart claimed:

The reason for being so emphatic on these three points is that there have been many charges and implications pointed toward microwave ovens. A case in point was the June 19, 1977, CBS television program, "60 Minutes", which gave a report on electronic pollution with erroneous implications about microwave ovens.

Mr. Verle Blaha of Litton Microwave Cooking Products, who accompanied Mr. Baumgart, explained that the original microwave

oven standard was first modified to provide an additional interlock, the second modification related to intrusion proofing, and the third involved the addition of a label in the service handbook and on the face of the oven. Mr. Baumgart emphasized that no changes had been made relative to the amount of radiation leakage that was permitted.

Further discussion revealed that there is no way for the customer to determine whether the amount of leakage changes with age. Instructions on the label warn the customer not to use the oven if it has been damaged or if the door is loose. Quality control procedures were also discussed as were the Association's efforts to review and evaluate all research relevant to microwave effects.

Mr. Lee V. Gossick, Executive Director for Operations, U.S. Nuclear Regulatory Commission (NRC), told the committee that his agency is responsible for the licensing and regulation of nuclear materials and facilities, including nuclear powerplants. NRC is concerned with assuring that such facilities are located, designed, constructed, and operated to properly protect people from the hazards of radiation leakage or accidents. NRC is also responsible for the safe storage, handling, and transportation of nuclear materials used in research reactors and laboratories, hospitals, and industry.

Mr. Gossick described the nature and extent of NRC's research program. He emphasized that it is primarily intended to support NRC's regulatory and licensing functions and is, therefore, of a confirmatory nature, as differentiated from development of reactor or safety system designs. The research program includes analysis of the movement of radioactive materials in the environment, interaction of radiation with plants and animals, and effects of ionizing radiation on people, e.g., potential health effects from occupational exposures and from environmental levels of radioactivity.

Mr. Gossick said that NRC is not aware of any new or emerging technologies which are likely to produce new radiation hazards, but is concerned that many known radiation sources require more attention than previously afforded. For example, neither naturally occurring radioactive materials nor accelerator-produced radioactive material is currently subject to NRC regulations. "In these areas," he stressed:

> The objective should be to assure that all radiation exposure, whether it arises in medical, commercial, industrial, military, or power production activities, is controlled with a uniformly applied, prudent public health policy derived from consistent application of the extensive base of scientific information on radiation effects.

A task force which recently completed a study of this situation has

> . . . recommended that NRC seek legislative authority to regulate these materials because they present significant radiation exposure potential and because of the fragmentary and non-uniform controls now available.

Mr. Gossick feels that on radiation-related matters there is considerable cooperation among Federal agencies, between Federal and State agencies, and among international agencies. Within the executive branch, both OMB and EPA have undertaken coordination roles in recent years.

Mr. Gossick believes that improved coordination is needed to provide (1) clearer definitions of jurisdictions among agencies, (2) requirements for analysis of the value of proposed regulations, including the effects of their implementation, and (3) guidelines for judgments on

the acceptability of risks. He added that some consolidation of Federal radiation activities might spark improvement in these areas and might reduce duplication, particularly between EPA and NRC. Of course, the important related issue of the alignment of authority between the Federal Government and the States must also be considered.

"For the present, there is some lack of balance in radiation protection and some costly duplication of efforts. The role played by the EPA within the current alignment of radiation protection responsibilities is central to achieving needed improvements." NRC supports EPA's efforts to exercise all of the authority it has inherited relative to both general environmental issues as well as medical and health issues.

Mr. Gossick outlined some of NRC's actions to protect workers who deal with ionizing radiation. He noted that prior to 1971, the practice was simply to require compliance with the radiation protection limits in NRC regulations. It was evident, however, that some workers were receiving radiation exposures within these allowed limits, but which could be further reduced with relative ease and at reasonable cost. Therefore, in 1971 the Code of Federal Regulations was amended to require that exposures be not only within limits, but "as low as practicable." This principle is implemented through the issuance of regulatory guides. Mr. Gossick submitted for the record a guide which was recently issued on occupational exposure control at nuclear powerplants. Additional plans will require licensees (a) to develop exposure control programs, (b) to meet minimum training requirements for workers and special criteria for temporary workers, and (c) to employ competent radiation protection personnel in both the design and operational phases of the nuclear facilities.

During a discussion with Senator Stevenson, Mr. Gossick explained that NRC guides suggest one way of achieving the required levels; licensees are free to use equivalent or better approaches for keeping exposures as low as practicable.

Senator Stevenson was assured that natural sources of radioactivity and accelerator-produced radioactive materials were the only two classes of material not covered by present controls. Mr. Richard Cunningham, Acting Director, NRC Division of Fuel Cycle and Material Safety, who accompanied Mr. Gossick, explained that radioactive materials produced by hospital accelerators will find extensive use in nuclear medicine. They will produce short-lived isotopes and will require qualified radiochemists and physicists to operate the equipment, manage the materials, and put them in the proper form for patient use. Mr. Cunningham does not yet have enough data to define the entire scope of this problem.

Dr. Roger Mattson, Director of NRC's Division of Siting, Health, and Safeguards Standards, addressed the question of research on ionizing radiation's effect on humans. He noted there was a large body of data going back 50 years or so. However, as we become concerned with lower and lower exposures and different kinds of radioisotopes, knowledge gaps become more apparent. There is a need for epidemiological studies that look for health effects of very low level carcinogens in large populations. NRC uses its small amounts of money and rather narrow interests to piggyback on the larger research efforts of ERDA or NCI.

Commenting on the studies of Dr. Irwin Bross, Dr. Mattson stated that Dr. Bross had been engaged in an epidemiological study called

the Tri-State survey. According to Dr. Mattson, Dr. Bross has used information developed in his study to conclude that NRC regulations do not furnish adequate protection from the harmful effects of ionizing radiation. Dr. Mattson told the committee that NRC has offered "to meet with Dr. Bross in a public meeting conducted by our Office of Standards Development to review in a technical sense his Tri-State study with peer appraisal, and try to derive what we can from the study for our regulatory purposes."

Senator Stevenson asked Mr. Gossick how NRC has responded to the extensive public criticism of the Rasmussen Study of Reactor Safety. Mr. Gossick indicated that NRC is assembling "yet another independent group" to review the adequacy of the Rasmussen report, and to assess the procedure by which the report was produced. Their report is expected in the fall of 1978.

Senator Stevenson asked if NRC is concerned about radioactivity from coal-fired generating plants. Mr. Mattson explained that none of the Federal regulatory agencies presently exercises control over such emissions, although EPA was considering some action. He is fairly certain that burning coal does produce some increase in the number of radioactive particles in the atmosphere, depending upon the kind of coal used. Senator Stevenson expressed concern that the United States may be shifting its emphasis from nuclear power to coal with no clear assessment of the new problems that might develop—e.g., polluting the atmosphere with excessive quantities of carbon dioxide or radioactive particles. He questioned where we would get all the water required to operate coal-slurry pipelines and whether the electric fields associated with high voltage transmission lines might not be hazardous.

Mr. Hal Peterson, who accompanied Mr. Gossick, reported that several effects had been attributed to high voltage powerlines. These include the production of toxic gases such as ozone, the induction of electrical shock from metal structures in the high voltage electric field of the wires, and a possible fire hazard due to spark discharges, radio and TV interference, and acoustical noise. There has also been some concern about possible neurophysiological effects, but these cannot be confirmed. Mr. Peterson offered to provide the committee with a summary of the known effects of nonionizing radiation from transmission lines. Of all these hazards, Mr. Peterson is most concerned with the induction of electric shock. NRC reported that no one is charged with regulating the siting or construction of coal-burning plants in order to avoid all of these problems. NRC feels that if such a responsibility were to be defined, it should probably rest with EPA or the States.

Mr. Gossick was asked to explain what had happened to 280 pounds of weapons grade uranium reported lost from the Apollo, Pennsylvania facility. He first pointed out the difference between lost or stolen uranium and "material unaccounted for" (MUF). MUF

> . . . reflects a problem that is encountered in the chemical processing of this material. The difficulty lies in measuring exactly how much you have in any given part of the process of fabricating the material—being able to measure scrap, being able to detect and account for small quantities of material held up in pipes, held up in the various processes. . . . The problem here is one of accounting. To our knowledge we have no evidence to lead us to believe that this material has literally been made away with and used for illicit purposes.

Mr. Gossick described some of the recent steps that NRC has taken not only to improve its accounting methods but also to provide more

vigorous physical security—even though there has been no evidence of theft. NRC outlined its present security measures relating to the transportation and storage of spent nuclear fuel rods.

While NRC is not conducting any research on the effects of nonionizing radiation, it believes that other agencies are operating at an adequate level. NRC also expressed satisfaction with its own level of effort and distribution of resources for reactor safety research, environmental and fuel cycle research and safeguards research.

Dr. James Liverman, Assistant Administrator for Environment and Safety, Energy Research and Development Administration,[2] began his testimony by identifying the elements of the nuclear fuel cycle which relate to biomedical and environmental issues. These include the release of radiation into the environment, its movement through the environment and where one might expect to find high concentrations, exposure of workers and the general population to ionizing radiation, and certain institutional questions.

Dr. Liverman submitted an inventory of research in all areas of environmental health and safety related to all of the technologies ERDA is developing. According to Dr. Liverman, the United States in 1976 invested more than $200 million for research and development in the environmental health, safety, operational safety, and control technology aspects of nuclear energy. This compares to $450 million for biomedical/environmental research on all kinds of energy-producing facilities.

Dr. Liverman described some of this research. The United States and Japan are jointly funding a study of radiation's effects on 109,000 people who were exposed to the atomic bomb blasts of more than 30 years ago. Another project involves 10,000 people who received injections of radioactive thorium or radium. Workers who have been exposed to radiation other than plutonium or transuranic elements over the total life of the Atomic Energy Manhattan District are the subject of an epidemiological study. Other studies involve only animal subjects and treat questions of carcinogenesis and mutagenesis. Environmental research is mainly concerned with possible radiation accumulation in various stages of the food chain.

Dr. Liverman mentioned the importance of developing measurement techniques for each of the 700 or more different radioactive isotopes. In cooperation with other agencies, ERDA has been involved in the development of accelerators for radiation therapy. It has also designed and extensively tested special casks for the safe transportation of nuclear materials.

The use of uranium mill tailings for landfill purposes in Grand Junction, Colo., has required a major ERDA effort to survey some 19,000 homes, schools, and other buildings constructed over these wastes. Total cost of the survey and corrective followup actions will be about $10 million or $11 million. Some 22 other sites in Western States must also be surveyed.

Dr. Liverman estimates that their cleanup will require an additional $80 to $125 million. A third cleanup problem involves 150 laboratories used during World War II Manhattan Engineer District. ERDA will need to resurvey all of these and clean up the 8 or 10 believed to have residual radiation in excess of current permissible standards. Dr. Liv-

[2] Now the Department of Energy.

erman cautioned, "We do not believe that any of these constitutes a current major health hazard. . . ." The major cost of additional clean-up jobs, involving an anticipated 1,000 or so contaminated facilities, may run as high as $3 to $5 billion by 1980.

Dr. Liverman concluded by describing the broad scope of inter-agency cooperation in such areas as the health and environmental impacts of energy technology.

Asked if OMB was trying to centralize all the research on ionizing radiation in ERDA, Dr. Liverman said he was unaware of any such attempts, but did recall a situation in which OMB and EPA shifted a small amount of research funding—$½ to $2 million—from EPA to ERDA. EPA conducts a complete review of the ERDA program.

Senator Stevenson asked Dr. Liverman about the problem of radioactivity from coal. Dr. Liverman stated that the amount of radioactivity and other toxic materials released depends upon the impurities present in the coal and upon the amount that is burned. He said:

> Currently, it is believed that there is more radiation released from the burning of some coals than from nuclear reactors in commercial use. Those levels, however, are still fairly small and are not above the maximum permissible concentrations that one would allow, and are not regulated at any time.

He suggested that some of the heaviest uranium deposits would probably appear in coal from West Virginia and Utah where there is a lot of uranium. Coal mines themselves are not regarded by ERDA as high radiation areas; methane is much more of a problem than radiation.

He thinks that the United States should address the problems that could arise from the use of these coals and that the research has not been adequate. The particulates expelled from coal-fired plants are of just the right size to reach the human lungs. Dr. Liverman offered to provide for the committee's files the detailed analysis of this problem which ERDA has recently completed.

Radiation from high voltage powerlines is another area of interest to ERDA. It is spending about one-half million dollars each year for research on the subject. "If the intensity is sufficient enough," Dr. Liverman said, "you could have neurophysiological effects."

Dr. Liverman presented some details of ERDA's disaster plan for the accidental release of radioactive materials into the atmosphere.

Dr. Liverman believes that regulations related to ionizing radiation exposure should be based upon the assumption that there is no safe level of exposure, that is, there is no threshold below which radiation exposure has no detrimental effect.

Dr. Liverman noted that it's fairly easy to identify the biological effects arising from high levels of exposure to mutagens or carcinogens. However, for low levels of exposure to a given pollutant—such as ionizing radiation—it is difficult to separate the effects of that particular insult from the effects of other pollutants in the environment.

As an example of the difficulties involved in identifying the effects of low-level exposures, Dr. Liverman told the committee,

> The calculations that have been done on genetic effects, for instance, indicate that you would experience some effects even at 170 milliroentgens per year. If you tried to determine this precisely in experimental mice, it would take about 8 billion mice and probably 8,000 years. In the meantime, evolution has taken place. This is obviously not a scientific question that is answerable.

Dr. Grover Wrenn, Deputy Director for Health Standards Programs, Occupational Safety and Health Administration, told the committee that radiation, ionizing and nonionizing is but one of the many aspects of worker safety and health for which OSHA must establish and enforce standards. He also pointed out that numerous other agencies have regulatory responsibilities relating to radiation in the workplace.

Dr. Wrenn was not confident that present standards for occupational exposure to radioactivity provide adequate protection or are based on sufficient data. He said the present standards, which were inherited by OSHA at the time of its formation, have not been reviewed in the 6 years since then. Dr. Wrenn explained that OSHA's limited technical resources in the standards-setting area have been concerned with new and more recently identified worker health hazards, particularly chemical carcinogens such as vinyl chloride, asbestos, arsenic, benzine, and other such substances. A new Office of Physical Agents Standards has recently been created to review the existing body of standards for both ionizing and nonionizing radiation, to review evidence regarding their adequacy, and to amend them as necessary. No deadline has been established for completion of this review.

Dr. Wrenn seriously doubts that OSHA was ever called to check workers' exposure to radiation in coal-fired powerplants. He agreed, however, that it would have authority to make such an inspection provided the plant was privately owned.

Senator Stevenson noted that according to Dr. Wrenn's formal statement, OSHA had conducted only 28 inspections for ionizing radiation health hazards during fiscal year 1976, and that this appears to be a minimum effort. In describing the nature of these inspections, Dr. Wrenn explained:

> Those were most likely inspections of a general occupational health nature during the course of which some question of radiation protection was discovered. It is possible that the inspection was specifically related to a question of radiation safety, but knowing our field activities generally, I would expect that those questions would have arisen in an inspection of a broader scope than simply radiation.

While Dr. Wrenn knew of no specific circumstances under which OSHA had examined airport baggage scanners, he assured the committee that a formal mechanism has been established by which a concerned employee can request an inspection.

Unreported radiation accidents were a matter of continuing concern for both OSHA and the Bureau of Radiological Health.

Dr. Elliott S. Harris, Director, Division of Biomedical and Behavioral Science, National Institute for Occupational Safety and Health, traced his agency's authority for radiation-related programs back to the Public Health Service Act. NIOSH was established by the Occupational Safety and Health Act of 1970 and charged with several responsibilities directly related to radiation safety and health. These include the conduct of research programs, the performance of hazard evaluations, field studies, morbidity and mortality studies, the development of recommended standards, the dissemination of information to employers and employees, the provision of technical assistance, and training and education programs. Many of these are concerned specifically with ionizing and nonionizing radiation.

Dr. Harris told the committee that NIOSH develops criteria documents relating to chemical and physical hazards for the purpose of recommending an occupational health or safety standard to OSHA. The goal is to identify the health effects produced by a substance or process and to recommend methods to evaluate and control the hazard. These documents undergo extensive internal and external review by management and trade associations, organized labor, academia, State and Federal agencies, and professional societies.

Dr. Harris added that NIOSH has already developed and transmitted to OSHA 65 criteria documents relating to various occupational hazards, including hot environments and ultraviolet radiation. However, only six of these have been adopted. Another 10 or 12 were reported to be in the rulemaking process. NIOSH expects to complete a variety of documents involving worker exposure to radiofrequency and microwave radiation, infrared radiation, and ultrasonic radiation during fiscal years 1977–81.

NIOSH has also initiated a study to survey the current knowledge of radiation-induced cancer. Dr. Harris believes this will help update the National Academy of Sciences 1972 report on "The Biological Effects of Ionizing Radiation." The agency is conducting an epidemiological study of radiation exposure involving uranium mining and milling operations. Dr. Harris said:

> It was this work which first identified the lung cancer problems among uranium miners. Efforts were initiated to control exposure, and a cohort of exposed workers is currently being followed as part of our surveillance activities. This research on uranium miners was also instrumental in developing field methods for measuring radon daughters, procedures for engineering controls, and medical monitoring procedures for the diagnosis of lung cancer.

NIOSH has assisted the FAA and the Air Transport Association in evaluating the potential exposure hazards to airport personnel working with X-ray luggage inspection units. The hazard was found to be minimal as employee doses were well below the OSHA exposure standard.

Dr. Harris noted that much of his agency's present and future radiation effort will involve nonionizing radiation. There are programs on visible, infrared, optical, ultraviolet, laser, radiofrequency/microwave, and ultrasonic radiation. As an example of these activities, he described a NIOSH criteria document on ultraviolet radiation. It reviewed the potential hazards, listed various areas requiring research, and told of progress in those areas. NIOSH will soon initiate a study to assess eye damage resulting from exposure to infrared radiation, where threshold levels have not yet been determined as a function of frequency. In fiscal year 1968 NIOSH surveyed 2,100 lasers in 200 occupational establishments in three States. According to Dr. Harris, "The safety and engineering control procedures were found to be marginal or inadequate for 40 percent of the lasers in use." In 1976, NIOSH published a compendium containing technical data on 2,500 laser devices manufactured after 1963. The data will be used by OSHA in drafting a standard for exposure to lasers.

NIOSH has measured the optical and radiofrequency radiation from cathode ray tubes in newspaper composition rooms where two young employees had developed bilateral cataracts. According to Dr. Harris, it has not been possible to establish that cataracts are related

to radiation emissions from these terminals. Along these same lines, NIOSH has developed a calibration and testing facility with standard sources and detectors to evaluate optical radiation hazards. A quality control assurance program has been initiated to check on the stability, accuracy, and reproducibility of the instruments. Dr. Harris believes "Accurate measurement equipment and survey techniques are essential for the monitoring and enforcement of RF and microwave exposure levels."

Occupational exposure to RF and microwave radiation will be treated in a criteria document to be published in fiscal year 1979. NIOSH has already become involved in some of these issues. For example, NIOSH was asked to investigate work hazards related to the Navy's TACAN radar system after two repairmen developed carcinoma of the pancreas. At all three sites surveyed, X-ray and microwave radiation were found within acceptable levels. However, a retrospective epidemiological study of TACAN repairmen is being considered.

In the radiofrequency band from 10–300 megahertz, Dr. Harris identified three problems. First, many employers do not even realize they are using RF radiation in their facilities. This may be one reason why estimates on the number of workers exposed to RF and microwave radiation vary from 50,000 to 21 million. A second problem in this area is the lack of survey instruments with which "near zone" measurements can be made in the field. The third problem is the limited information that is available on the biological effects of radiofrequency radiation used in industry.

NIOSH field studies revealed:

> . . . 75 percent of the workers using RF sealing and heating equipment were exposed to RF radiation levels higher than the present occupational exposure guideline. A majority of these workers were females of child-bearing age. Because recent literature indicates that exposure of pregnant animals to RF radiation may harm the fetus, we have started animal studies to determine threshold levels for effects from RF exposure.

Dr. Harris concluded with a review of his agency's training efforts. Its courses are available to any Federal or State employees and to other interested health and safety professionals.

Dr. Harris and his associates from NIOSH were asked to identify the major sources of employee exposure to ultrasonic radiation. Jet airplanes and ultrasonic cleaners headed the list. There are medical uses for ultrasonic devices, like cancer diagnosis or defining the position of a fetus. However, there are no standards for the industrial use of ultrasonic radiation. Nor are there any standards regarding exposure to ultraviolet, visible, or infrared radiation from welding arcs.

Dr. Harris described a long-term study (3–5 years) that NIOSH is conducting to determine threshold levels for the effects of radiofrequency exposure.

Heating and drying operations in food processing, textile and forest products industries were listed as the principal sources of worker exposure to microwave radiation. Ovens and medical diathermy machines are among other important sources. Mr. William E. Murray, Chief, Radiation Section, who accompanied Dr. Harris, told the committee that the present OSHA regulation does cover worker exposure over the frequency range of 10 megahertz to 100 gigahertz. However, he was uncertain whether the guidelines were valid in the 10 to 300 megahertz range. This was because there is too little information on biologi-

cal effects of RF radiation and because the guides are stated in the "wrong terminology."

The major sources of worker exposure to ionizing radiation include X-ray devices for industrial radiography and nondestructive testing, particle accelerators for research and nondestructive testing, and radionuclides such as uranium and radon.

Dr. Harris told the committee that NIOSH is negotiating with ERDA for a contract to study the potential hazards of radioactivity in mining, gasification, liquefaction, and coal burning. The study will, of course, focus only upon worker exposure and not on the dangers for the general population.

The lack of accurate, portable survey instruments is a serious problem for both NIOSH and OSHA, according to Dr. Harris. The NBS has developed several one-of-a-kind instruments for NIOSH, but it is difficult to interest manufacturers in producing these instruments commercially. In other cases, Dr. Harris said, ". . . it is not a question of the lack of funds or the lack of desire. It is the lack of technology."

Dr. David Rall, Director, National Institute of Environmental Health Sciences (within HEW), told the committee that shortly after NIEHS was created a study of the biomedical effects of nonionizing radiation in the environment was proposed. As part of its 1978 budget proposal to the Congress, the Institute prepared a list of research needs in environmental health, with the help of more than 80 scientists from Government, industry, and educational institutions. Dr. Rall submitted for the record a chapter which addressed the broad issue of physical environmental factors and made recommendations regarding research needs in this field, including nonionizing radiation.

Dr. Rall described some of the research on the use of ionizing radiation as a diagnostic or clinical tool currently under way in other NIH Institutes. The National Institute of Neurological and Communicative Disorders and Stroke is working on Computerized Axial Tomography. The NCI has several programs aimed at reducing diagnostic exposure, and the National Institute of General Medical Science has a variety of research projects concerned with radiation detection and imaging systems as well as the development of computerized methods for interpreting radiological images and of new radiopharmaceuticals. However, Dr. Rall cautioned, "The broad area of environmental and human health effects of ionizing radiation is the primary responsibility of ERDA; the NIH has deferred to that agency in this area."

NIEHS activities include joint sponsorship with NCI of epidemiological studies to determine if groups of patients exposed to diagnostic or therapeutic radiation (for example, radiotherapy for ringworm of the scalp or thyroid scans with radioactive iodine) show long-term health effects. A similar program with NCI defined the lung cancer risk for uranium miners. NIEHS is also committeed to research aimed at broad understanding of health effects of microwaves. Their accomplishments include the development of microwave exposure systems for laboratory use which provide well characterized microwave fields as well as a controlled temperature and humidity environment.

NIEHS has studied the effects of microwaves on teratology (birth defects), fertility, and immunology. Embryos that were exposed to 5 mW/cm^2 of microwave radiation throughout the developmental period showed no gross deformities if the temperature was not allowed to

rise above normal developmental levels. However, small but statistically significant effects on hemoglobin and white cells numbers were measured. When its new laboratory becomes available in early 1980, NIEHS plans to significantly increase its in-house efforts on the biological effects of nonionizing radiation. The Institute is currently sponsoring research on (a) the effects of long-term, low-level microwave exposure, (b) the effects of 60-cycle electric powerline fields, and (c) the effects of prenatal microwave irradiation.

NIEHS employees are part of the United States/U.S.S.R. medical scientists exchange program and have attempted to replicate some of the Soviet studies on behavioral effects of microwave radiation. Unfortunately, as explained by one of the NIEHS panelists, this has been very difficult because most of the research papers do not contain enough information to allow duplication. The results have not been replicated because in many cases it was impossible to repeat the experiment. Dr. McRee described an experiment which is to be conducted simultaneously in both the United States and the U.S.S.R. The project should be completed by fiscal year 1978.

Dr. Rall agreed with previous observations that the average person's exposure to diagnostic and therapeutic radiation is increasing in the United States. In order to deal with this problem and protect the public from damage due to accumulated doses, Dr. Rall suggests continuing the development of diagnostic procedures which either do not use ionizing radiation or which use as low a dose as is consistent with the required need. Physicians should use X-rays as sparingly as is consistent with good medical practice. Improved public education would also be helpful.

Asked to comment on the potential correlation between pancreatic cancer and microwave exposure of Navy radar operators, Dr. Rall thought it was too early to say whether a correlation exists. Dr. Miller, also of NIEHS, suggested that such observations be considered as hypotheses which have to be tested by observing people exposed to radar to see if they develop cancer of the pancreas, or by examining the histories of people with pancreatic cancers to see if they were exposed to radar. NIEHS has no plans to conduct such studies.

Dr. Rall was asked, "If you could start from scratch, how would you organize the research and regulatory activities of the Federal Government with respect to radiation?" Dr. Rall responded:

> I am a pluralist and not a monolithist, if I may make up that word. The concerns of an agency interested in developing energy for the United States are so different from those of an agency interested in protecting the health of the worker that I see sense in having each of them have an effective research program. By the same token, these programs must be strongly and effectively coordinated so each knows what the other is doing, and if and when they duplicate, it is clearly an intentional duplication because the results seem different.
>
> I personally am also convinced that one needs outside research organizations independent from either those who do the regulation or those who are promoting a project. The independent research organizations provide the new ideas, the new leads, and bring up the disturbing facts that cast doubt on old regulations. What I am saying is the organization, although it looks messy on a paper full of boxes, may not be that bad.
>
> The coordination in nonionizing radiation from OTP was very useful and enhanced the effectiveness of the limited resources quite significantly.

On the other hand, Dr. Rall feels there are some clear advantages to centralization of activities with ERDA's handling of ionizing

radiation. However, he said, "There are tendencies for centralized research efforts to become ingrown and not as imaginative as others."

Dr. William J. Thaler, Acting Director, Office of Telecommunications Policy, Executive Office of the President, emphasized OTP's role of assuring that the use of nonionizing electromagnetic energy does not harm man or his environment. This function is part of OTP's general responsibility to coordinate telecommunications activities and associated research within the Federal Government. Dr. Thaler told the committee:

> The Federal program, coordinated by OTP, is designed to develop a sound scientific understanding of the interaction of EMR energy with living systems. This will serve as a basis for evaluating possible biological risks of given levels and conditions of EMR, and for developing appropriate controls which may be warranted to insure safe and effective use of the spectrum. Five years ago, OTP recommended and undertook the coordination of a multiagency program to investigate biological effects of this energy.

OTP's responsibilities involve radiofrequency radiation, which like visible and infrared, is nonionizing. Dr. Thaler is concerned that the use of the term "radiation" often elicits confusion. He explained that a quantum of radiofrequency radiation has far less energy than a quantum of ionizing radiation which can break molecular bonds and do significant biological damage. He noted that the use of radiofrequency energy has been growing rapidly and cited such examples as radio and TV broadcasting, citizen's band radio, radars, air and marine navigation and safety systems, and emergency medical services. The spectrum is also used in industrial processing, medical equipment and consumer products.

Dr. Thaler identified the 1957–1961 DOD Tri-Service program as the first major U.S. effort to increase our knowledge of the biomedical activity of nonionizing radiation. Studies demonstrated some of the harmful effects of microwave heating at power density levels around and above the 10 mW/cm^2 occupational exposure standard. Dr. Thaler noted that after 1961, U.S. research on nonionizing radiation came to a near standstill. However, he said:

> Throughout the 1960's there was an increasing awareness of apparent differences between the United States and the Soviet concepts of the levels at which hazards from nonionizing radiation occurred. U.S. literature showed harmful effects from short exposures at high milliwatt per centimeter levels, while the Eastern literature claimed harmful effects in the low milliwatt per square centimeter and in some cases even the microwatt per square centimeter levels.

Also, he said:

> The Eastern countries established standards with maximum permissible exposures considerably lower than ours. Their observations included the effects on the nervous system and behavior, differences between various frequencies and waveforms, long-term, low-level exposure effects, and those associated with measurable heating.

In 1967, OTP's predecessor, the Office of Telecommunications Management, established the Electromagnetic Radiation Management Advisory Council (ERMAC) to provide a central focus and review progress in this area. ERMAC conducted an extensive review of scientific knowledge, research requirements, the status of research programs, and funding levels. They recommended guidelines, research priorities, and increased funding for a coordinated program of investigation among responsible Federal departments and agencies. The ERMAC is now reviewing its first 5-year plan in light of more recent research and is preparing updated guidelines for future efforts.

Dr. Thaler listed ERMAC's basic program objectives:

To determine the biological effects of radiofrequency radiations;

To determine the health and biological significance of any effects, and to evaluate risk;

To establish a sound scientific basis for any remedial and/or control measures; and

To ensure that U.S. safety criteria provide an adequate margin of safety.

Dr. Thaler emphasized:

The research program to date has identified no positive evidence of harmful effects to man at the levels of exposure normally encountered by the general population. No crisis has been found to exist. No cause for public alarm has been identified. We must, however, be absolutely certain that nothing has been overlooked and we recommend continued and accelerated pursuit of the necessary research.

Dr. Thaler feels that one of ERMAC's major contributions was the recommendation that OTP, as an independent and impartial entity in the Executive Office of the President, serve as an overview and coordinating body with assistance from the Council. OTP's role includes emphasizing the importance of this research among other competing agency priorities and attempting to ensure that the overall goals are being adequately addressed.

Dr. Thaler explained some of the problems of conducting research on the biological effects of electromagnetic radiation. He reported that some biological effects have been observed in experiments with small laboratory animals at levels around and below 10 mW/cm^2. These effects include changes in learned behavior or task performance, radiation perception, and apparent alterations in electrophysiological measurements of nervous system activity. However, Dr. Thaler emphasized:

These do not necessarily imply hazards to man for many reasons. For example, differences in size and mass between humans and laboratory animals with respect to frequency and power density are among many factors which need to be taken into consideration in assessing or interpreting this research.

In assessing radiation's impact on man, Dr. Thaler believes that it is first necessary to develop a realistic picture of actual exposure environments and the populations involved. Utilizing "somewhat limited" data, Dr. Thaler estimated that radiation levels in most environments normally encountered by the general public do not exceed one microwatt per centimeter squared, 10,000 times less than the present occupational safety standard.

Dr. Thaler identified five major problems and deficiencies in the present Federal program. (1) Electromagnetic radiation research must compete for resources with many other agency programs, some with more urgent priority within the agency's mission. (2) Research requiring relatively large and stable funding is beyond the particular resources of any individual agency. (3) Basic research is not being funded at a sufficiently high level because of the mission orientation of most agencies. (4) The public attitude toward radiation causes numerous problems; the material appearing in the press is sometimes limited in scope, out of context, and difficult to interpret. (5) There are apparent differences between Eastern European and Western research and safety standards which further adds to the confusion.

Dr. Thaler concluded by identifying four outstanding research needs and priorities:

(1) Experiments to investigate effects of long-term relatively low-level exposure, (2) studies of people exposed to radiation in specific occupational or experimental circumstances, (3) increased investment in basic research, including investigations of mechanisms of biological interaction, and (4) additional development and refinement of techniques for computing comparable doses of radiation, for measuring internal energy fields and energy distribution, and for extrapolating laboratory findings to man.

During the discussion period, Dr. Thaler agreed with Senator Stevenson's observation that the exposure of the average person to radiofrequency radiation is increasing. He feels this is due to the increased use of radiofrequency sources in broadcasting, radars, and such. "The proliferation of equipment," he said, "certainly means on the average a general rising level of exposure." This trend is expected to continue in the future, but the rate of increase cannot be predicted because of uncertainties in future technological developments.

Dr. Thaler was asked to explain why research on microwave bioeffects did not continue throughout the 1960's. He thought it was because researchers believed microwaves produced only thermal effects which would not cause problems if exposures were limited to 10 mW/cm^2 or less.

Combining OTP's coordinating role for nonionizing radiation research with that of another agency at the same level responsible for regulation and research on ionizing radiation did not appeal to Dr. Thaler. He feels that the technical problems, the interaction mechanisms, and the biological effects are completely different.

The adequacy of present funding was also discussed. According to Dr. Thaler, the Federal Government is now spending a total of about $9 million for research on the biological effects of nonionizing radiation. He personally recommends a level two to three times this high. In this regard, OTP's only role is to try to encourage each agency to establish a funding level enabling it to meet the goals and objectives that ERMAC and its interdepartmental working group have established. Dr. Thaler is not anxious to have an expanded authority over funding, as agencies might then feel that OTP was imposing its will upon them.

Ms. Janet Healer, who accompanied Dr. Thaler, was asked about OTP's involvement in the NASA–ERDA solar power satellite. Ms. Healer indicated that OTP was aware of the proposal and that both ERMAC and its scientific working group had been briefed. It has not yet been determined what research needs to be done in support of this activity. OTP expects to be deeply involved in the entire issue as it develops.

High intensity magnetic fields are not a major concern to OTP. Dr. Thaler, however, mentioned that one of his former associates had noticed some very interesting biological effects caused by the high magnetic fields around superconducting magnets. Similar strong fields may also be encountered around magnetohydrodynamic facilities.

Senator Stevenson asked Dr. Thaler if enough research had been conducted to justify funding a major study on the effects of nonionizing radiation—one that would be similar to the earlier BEIR report (Biological Effects of Ionizing Radiation). He answered that we have "... nowhere near the level of information that would make a BEIR-type study reasonable." However, he added that a study by an inde-

pendent body like the National Academy of Sciences could be useful in focusing on two areas: first, a general, independent review of what has been done, and more importantly, as Senator Schmitt mentioned, a projection of future techniques and equipment. Dr. Thaler thinks that somebody ought to look at present and emerging technologies to forecast what environmental levels of microwaves we might expect by the year 2000.

Mr. Charles Hardin, member and past chairman, Conference of Radiation Control Program Directors and manager, Kentucky Radiation Control Program, explained that the conference was formed 9 years ago to serve as a forum for the exchange of radiation health and safety information between State and Federal agencies as well as between States themselves. The goal of the conference is to assure that patients receiving diagnostic or therapeutic radiation, workers in radiation areas, consumers, and the general public at large receive the least radiation exposure consistent with the benefits to be derived from that exposure.

In keeping with this goal, Mr. Hardin said that several task forces have been established to evaluate, discuss, and subsequently to recommend specific actions to reduce identified problems. As examples of these activities, Mr. Hardin submitted the "Task Force Report on Bonding and Perpetual Care of Nuclear Licensed Activities" and a draft copy of the "Task Force Report on National Radioactivity Contamination Problems."

Mr. Hardin summarized the extent of State activities in radiation control: (1) All but two States, Puerto Rico and the District of Columbia, had enabling acts for radiation protection regulations; (2) Twenty-five States have signed agreements with the NRC under authority of the Atomic Energy Act as amended; (3) Forty-five States, Puerto Rico and the District of Columbia have regulatory programs in medical/dental X-ray control; (4) Forty-three States, Puerto Rico and the District of Columbia have regulatory programs in industrial X-ray control; (5) Twelve States and Puerto Rico have enabling legislation for licensing the users of X-rays. Only three States and Puerto Rico have implemented credentialing programs, with two States scheduled to become operational in the immediate future. Eight other States have proposed legislation relative to use regulation. Mr. Hardin said that in the area of nonionizing radiation 21 States have specific statutes relating to the control of nonionizing sources.

The inspection of radiation sources for compliance with established health and safety regulations was cited as one of the major radiation protection activities at the State level. In fiscal year 1975, for example, over $11 million was expended by the States on radiation protection activities, including over 25,000 dental and 27,000 medical X-ray inspections. Over 3,000 inspections were conducted regarding the proper use of radioactive materials.

Mr. Hardin listed the current radiation activities which the conference plans to discuss. These include: (1) The reduction of unnecessary radiation exposure from X-rays used in medical practice. He identified four contributing factors to unnecesary exposure—(a) inadequate training of operators of X-ray sources and nonradiologist practitioners, (b) nonefficacious use of X-ray sources, (c) inadequate quality control programs in X-ray facilities resulting in retakes of radiographs, and (d) improperly designed X-ray systems. (2) The

reduction of unnecessary radiation from radioactive material used in nuclear medicine. The major contributing factors in this area are (a) inadequate training in radiation protection and (b) nonefficacious use of certain radioactive materials relative to other materals. (3) The reduction of radiation exposure from various environmental sources, both ionizing and nonionizing. Examples of sources which contribute to this environmental exposure are (a) ionizing sources existing in nature, such as radioactive materials in phosphates, (b) manmade and natural ionizing sources from the uranium fuel cycle, such as mill tailings and radioactive wastes, and (c) nonionizing sources, such as microwave and radiofrequency transmissions. (4) The reduction of radiation to the radiation worker, both from ionizing and nonionizing sources, including radioactive materials and X-rays used in industrial radiography and medical fluoroscopy. (5) The reduction of radiation exposure to the consumer from both ionizing and nonionizing sources, such as TV sets or microwave ovens. The conference believes there is a need for standards on microwave exposure limits for people in addition to source emission standards. (6) The problems of laser radiation, a nonionizing source used in industry and educational institutions. The conference considers this to be a source of unnecessary exposure to workers, students, teachers, and in some cases the general public at large.

Mr. Hardin wanted to bring four major issues to the attention of the Congress: (1) the loss of Federal Government training grants for State radiation protection personnel, especially in the areas of X-ray and environmental protection; (2) overlapping Federal jurisdiction in radiation protection activities; (3) loss of direct Federal financial support to State radiation control programs, (4) the lack of uniform national criteria and/or standards, particularly in the areas of naturally occurring or artificially produced radioactive materials, or guidelines on the siting and perpetual care of low-level radioactive disposal facilities. Since States have the responsibility for long-term perpetual care, there needs to be national guidance and criteria on what constitutes an acceptable site for the disposal of low-level radioactive waste.

Mr. Hardin mentioned that in 1973, the Conference of Radiation Control Program Directors adopted a resolution requesting Congress to consider consolidation of the various Federal agencies on radiation protection. The conference still supports this approach. However, they would not combine regulatory with nonregulatory agencies. If consolidation is not feasible, the conference would like to see responsibilities clearly and concisely distributed among the various agencies and a clear statement of which agency has the lead responsibility in each particular area where more than one agency is involved.

Mr. Hardin does not regard radioactivity from coal as a serious problem. He reported that studies by a group called MESA in the Department of Interior found very little hazard to coal miners; however, he thinks there is need for research on the release of radioactivity to the environment which accompanies combustion. States do not monitor radiation at coal-fired generating plants.

The conference believes X-ray operators should be accredited. Mr. Hardin suggests that accreditation be handled by the States with guidance from the Federal Government.

Mr. Hardin sees no need to change BRH regulations to include old X-ray machines. The States conduct inspections, and they can regulate all X-ray machines—new or old. He does, however, believe that more States could be participating under contract with BRH to inspect new machines. Mr. Hardin reported that some States are unwilling to establish contracts with the Federal Government because they feel such funding is too unstable. They are afraid that as soon as people were hired, equipment purchased, and the program operating, funding would be cut off. They find it hard to get money from State legislatures to conduct programs which produce negative results, i.e., people don't get cancer.

While States are not involved in inspecting research equipment which produces either ionizing or nonionizing radiation, Mr. Hardin feels that such equipment should be subjected to the same rules and regulations which apply to industrial, medical, and other uses. In some areas he feels that operators of research equipment are less careful than other operators.

Mr. Hardin feels that radium, a naturally occurring radioactive element which is not included under the Atomic Energy Act, represents as much of a potential unnecessary exposure hazard to the population as any of the materials under the act. His concern is not for radium in the ground, but rather for that which is being used for medical and industrial applications. About five States have strong, active licensing and enforcement programs for these materials. Mr. Hardin feels there may be a need for Federal legislation covering these materials.

Mr. Hardin has recommended that exposure to radiation from microwaves, radar, and radio frequencies be reduced; however, he has seen no evidence of biological effects resulting from such exposure.

Dr. Richard Setlow, senior scientist, Brookhaven National Laboratory, testified on behalf of the National Academy of Sciences, National Research Council (NAS/NRC). He told the committee, "The congressional charter under which the NRC operates, directs the Academy to 'investigate, examine, experiment and report upon any subject of science or art' whenever called upon by any department of the Government. The Academy has been engaged in such studies on behalf of the Federal Government for over 100 years." After describing some of the Council's recent studies, Dr. Setlow pointed out that a number of more significant ones have been statutorily mandated by the Congress.

Dr. Setlow outlined NAS/NRC's proposal to conduct a comprehensive 2-year study of the current state of knowledge of the health effects of nonionizing radiation. This would include the effects of microwaves but not visible light or infrared radiation. A draft contract proposal had been prepared and discussed with a number of Federal agencies, including OTP, EPA, the Departments of the Army, Navy, and Air Force, OSHA, and BRH.

The Academy's study would be divided into two major parts. The first, expected to cost $400,000, would be a committee effort involving biologists, psychologists, engineers, physicists, and others who would collect information by reviewing published reports, conducting workshops, symposia, or public meetings, calling upon specialized consultants, et cetera. The final report would provide: (a) conclusions, insofar as the available data permits, regarding the biological effects of micro-

waves and other nonionizing radiation, (b) recommendations, insofar as possible, to serve as a basis for safety guidelines for human populations, and (c) identification of critical gaps in the scientific literature with a recommended research program to provide the missing information.

The second part of the Academy's proposal, which would cost about $500,000, involves a continuation and intensification of the epidemiological study of 40,000 Navy veterans of the Korean war, one-half of whom were exposed to some amount of microwave radiation; the other half belong to a control group not so exposed. This would involve an examination of medical histories from the time of exposure to the present.

In response to an earlier written request from the committee, the Academy has developed a proposal to examine emerging technologies which may utilize radiation in order to anticipate and prepare for protection against radiation emitted by these new technologies. Another study under consideration would involve the impact on over-the-air communications systems and other microwave-utilizing systems that would result from regulatory action on nonionizing radiation.

Since the Academy speaks only through reports published by its appointed committees and no committee has yet studied the question, Dr. Setlow was unable to report for the Academy on the suitability of existing standards for nonionizing radiation. His personal view is that the existing occupational standard is adequate for the present. He believes, however, that an upper limit is needed for exposure of the general population. He believes this new limit should be set at 1/10 of the occupational level until enough data have been accumulated to judge its adequacy. He added, "While there's no serious evidence that there's a bad effect at the moment, I don't want to be put in the position of saying there never will be a bad effect."

Dr. Setlow noted that we know comparatively little about the long-range effects of microwave radiation on people, and believes that acquiring such knowledge will be more difficult than studying the long-range effects of ionizing radiation. The difficulties include a lack of dosimeters for measuring nonionizing radiation exposure (comparable, for example, to the film badges that record exposure to ionizing radiation). In addition, there is only a very crude estimate of general population exposure levels for nonionizing radiation. Dr. Setlow also considers the effects of nonionizing radiation to be much smaller per unit of dose than those of ionizing radiation, especially the effects on simple molecules and simple cells.

> Therefore, we don't have a background of basic biology, if I could call it that, which enables us to extrapolate theoretically to large-scale systems, so we are forced to rely on experiments on animals and to collect what epidemiological data we can on people. . . . Yet, there doesn't seem to be any tremendous hazard, as far as one could perceive, from short-term studies at the present time.

Dr. Setlow was also concerned about insuring the continuing safety of radiating devices in homes.

Dr. Alvin G. Lazen, Associate Executive Director, Assembly of Life Sciences, National Academy of Sciences, who accompanied Dr. Setlow, was asked to summarize the Academy's report to the Navy regarding Project Seafarer, a proposed communications system whose underground grid-like antenna would run through a portion of Michigan's upper peninsula. Dr. Lazen reported that along the antenna, "The

effects of the electric fields and the magnetic fields are so small that they probably present no hazard to health." At the antenna's ground terminal, however, there is a higher electric field with some potential for hazard.

There was a question about the possible hazards to people in the immediate neighborhood of high-powered microwave transmitters for satellite communications. While neither Dr. Setlow nor Dr. Lazen could estimate the degree of potential hazard, Dr. Setlow concluded that if such transmitters caused any major effects, they would have been observed by now. The problem is with small effects. All one can say is there is no apparent large effect. Regarding potential cumulative effects of nonionizing radiation, Dr. Setlow responded that no good data exist.

Finally, Dr. Setlow said he did not believe the NAS study of emerging technologies would create an environment discouraging research or development in new areas. He believes that identifying potential problems before crises develop allows time to adapt in less painful ways without altering the environment.

Mr. Richard Bauer, president of the American Society of Radiologic Technologists, reported that the ASRT has for years been concerned about unnecessary medical radiation to the patient-consumers of the United States. Quoting from previous ASRT testimony before this committee, he said: "The ASRT wishes to make a matter of record the firm conviction of its members that patient exposure should be reduced to the absolute minimum necessary for appropriate diagnostic information."

The Radiation Health and Safety Act of 1968 established performance standards for radiologic equipment, but, Mr. Bauer noted, "No equipment can be any better than its operator." Without sufficient knowledge, "the operator has the potential to damage not only the patient's health but his own as well. Moreover, the patient-consumer is rarely in a position to judge either the qualifications of the operator or the quality of the examination."

Mr. Bauer states:

> Since the enactment of Public Law 90–602, the ASRT has gone on record in each succeeding Congress in support of the enactment of Federal minimum standards of education for radiologic technologists. There are currently an estimated 130,000 to 150,000 operators of radiologic equipment in this country. Approximately half of these individuals have voluntarily submitted to examination and have met the educational standards prescribed by the profession. The remaining 50 percent have no officially recognized qualifications.

Mr. Bauer indicated that some sort of accreditation program had existed prior to 1971. Since that time, the Public Health Service has been studying the broad subject of accrediting health manpower. A final report may soon be available, but Mr. Bauer is concerned that implementing its recommendations "will be a very lengthy, time-consuming process." EPA was reportedly developing Federal radiation guidelines for diagnostic X-rays to reduce unnecessary radiation exposure of patients, including that caused by inadequate operator performance, but those guidelines will apply only to Federal agencies. EPA is now awaiting Presidential approval. "In the absence of conclusive action by a Federal agency," he added, "the ASRT continues to believe that Federal legislation is the best approach to insure operator competence in the use of X-ray equipment." At its 1977 an-

nual meeting in Washington more than 2,000 members of the ASRT unanimously adopted resolutions in support of the enactment of S. 1695, the Radiation Health and Safety Act of 1977 introduced in the Senate by Senator Jennings Randolph.

During the discussion session, Mr. Bauer explained that the American Registery of Radiologic Technologists lists 60,000 to 65,000 currently practicing technologists who have had at least a 2-year education in a program approved by the AMA and have passed an examination administered by the Registry. Most of the educational programs are in hospitals approved by the AMA; courses include anatomy, physiology, radiation safety, radiation biology, radiographic positioning, and medical ethics. While there is no requirement for continued education, the Society has instituted a voluntary program.

Dr. Bauer reported that about 12 States have enacted widely varying licensing laws, but not all of them have been fully implemented.

All radiologic technologists are required to wear film badges which monitor their exposure to radiation.

Dr. Ernest Ambler, Acting Director of the National Bureau of Standards, submitted a statement for the record. The NBS report indicated that substantial gaps exist in the national radiation measurement system. For example, NBS notes, "One of the most serious deficiencies in the present system is the lack of organizations or institutions which can and will operate at the intermediate level." In particular, NBS sees a need for increased calibration capability at the State level. This capability is required to insure the accuracy and uniformity of field measurements, which should be traceable to the national standards of physical measurement maintained at NBS. When that traceability does not exist, wide variations can appear in measurements of the same quantity. For example, NBS reports, "In a recent survey in southern Florida, the Bureau of Radiological Health found inaccuracies as great as 100 percent in the instruments used by medical personnel."

NBS believes research into the biological effects of electromagnetic radiation is seriously needed. However, measurement methods and standards do not exist or are inadequate for measuring complex electromagnetic fields such as those generated by pulsed signals, impulsive signals, and multiple-source environments. New instruments will need to be developed to measure these complex signals, and new dissemination mechanisms will need to be established to make this capability available to the States, Federal agencies, and private researchers.

The NBS report also identified several other measurement areas which lack basic measurement standards. Examples include ultraviolet radiation, neutrons, high-energy X-rays, and ultrasonics. NBS cautions that researchers will be unable to establish the safety of various radiation levels without uniform and accurate measurements of radiation exposure. Nor can reliable diagnosis and therapy be provided when there are excessive uncertainties about the amount of radiation delivered.

APPENDICES

A.—ADOPTING ADVANCED DIAGNOSTIC EQUIPMENT CAN REDUCE X-RAY EXPOSURE

A. PROBLEM STATEMENT

For over 75 years the medical profession has used X-ray equipment and radiographs to identify internal injuries such as fractures and lesions and to detect early symptoms of disease. In some cases such usage represents the only available non-surgical diagnostic method; in others it provides the quickest and most economical approach, and in still other cases it serves to corroborate conclusions otherwise determined.

During the early history of medical X-ray usage there was little awareness of the potential health hazard of such radiation and correspondingly little control over dosage absorbed by the subject. As the hazards of ionizing radiation became widely recognized, controls were adopted and some usages curtailed. Cessation of the use of X-rays in shoe stores so people could see their toes through their shoes was clearly justified and carried no offsetting disadvantages. It is regrettable, however, that one must curtail the use of mammography or upper body chest X-rays which can detect breast or lung cancer that might not otherwise be detected.

These conditions generate a need for X-ray technology—equipment and procedure—that can not only retain the benefits but also reduce the risks of X-ray diagnostic procedures.

B. CONVENTIONAL X-RAY EQUIPMENT

X-ray diagnosis generally involves formation of an image on photographic film. The principal difference between such an X-ray picture, or radiograph, and everyday photography is that the latter is formed by light (a form of electromagnetic radiation) *reflected from the subject* onto the film, whereas an X-ray radiograph is actually a shadowgraph formed by the *passage of X-rays* (also a form of electromagnetic radiation of shorter wave length) *through the subject* onto the film. The ensuing radiograph depends for its information content on the varying degrees of *absorption of X-rays* by body material. In other words, X-ray absorption by the body tissues, bones and organs of the subject is essential to the process. The quantity absorbed (measured in rads) is related to the ionizing intensity of the X-ray beam (measured in milliroentgens, mR), the nature of the body tissues and organs and the characteristics of the radiation, particularly the applied voltage at the X-ray tube and the nature of any filtering used.

For upper body or chest examinations typical exposure levels range up to 200–400 mR in most hospitals and clinics. These exposure levels are required to obtain a suitable radiograph (an average optical density of 1.0 units over the image area of concern to the radiologist) utilizing conventional film-screen cassettes. These cassettes consist of film coated with emulsions of silver halides, backed by or sandwiched between intensifying screens of calcium tungstate. Such screens provide several fluorescent light photons for every X-ray photon absorbed—thereby intensifying the image developed on the film and reducing two-to-threefold the intensity of the incident X-ray beam to which the subject must be exposed.

Under typical hospital procedures the radiologist, an M.D. with specialized training, determines the exposures and required equipment settings for various diagnostic X-ray procedures. A technologist operates the equipment and prepares the radiograph. The latitude accorded to the technologist to vary exposures and/or repeat exposures, if necessary to produce satisfactory radiographs, varies with local skill levels and practices. Only five States require training and certification of radiologic technologists.

C. AVAILABLE EQUIPMENT AND EMERGING TECHNOLOGY

With the marked expansion in the level of dollars available for health care in general, and hospital services in particular, it is not surprising that an array of new equipment has been developed for X-ray diagnostic procedures. Some examples suggest the *potential* for alleviation of excess exposure problems.

1. Rare earth intensifying screens

Use of rare earth intensifying screens (a spinoff from color TV screen development) can reduce by a factor of from 2 to 10 the X-ray exposure level required for various diagnostic procedures with otherwise conventional X-ray equipment. Such screens of Lanthanum or Gadolinium intensify the image obtained on the film either by increasing the percent of X-ray photons absorbed in the screen, or by increasing the number of light photons produced for each X-ray photon absorbed, or both. Such image intensification permits exposure reduction.

2. Scanning beam radiography (not tomography)

One prototype system has been under evaluation at the University of Maryland Trauma Center. It combines a slow (15 seconds) longitudinal traverse of the X-ray tube positioned under the table supporting the subject with a very high speed lateral scan of the subject by a narrow pencil point X-ray beam (1 square mm in crossection) developed at about 100 kV and 100 ma. This lateral scan is executed once every 8 milliseconds. Although the duration of the exposure is 15 seconds, no point in the body is exposed for more than several microseconds. Since all the X-rays reaching the detector come from the same point in the body, the effects of scattering are minimized, resulting in an improved signal-to-noise ratio. The scanning beam is received by an overhead sensing system connected to appropriate electronic processing and computer storage systems. These produce a real-time image in a cathode ray tube (CRT) permitting immediate diagnosis by the radiologist. The quantity of information produced by this technique may be equivalent to many conventional radiographs, each with different exposure but with the same view. For an upper body (chest) examination the subject is reportedly exposed to substantially less radiation than for a conventional chest radiograph.

3. XERG mammography

This is a system featuring a departure from conventional radiography. Instead of a film-screen cassette, the detector consists of a gas-filed, ion chamber in which the ion current formed by the passage and absorption of the X-ray beam electrostatically charges a coated mylar sheet. This charge is retained long enough to trap a suitable toner on the mylar sheet; the combination achieves very much the appearance of a conventional X-ray radiograph.

Tests and evaluation at the Hopkins Medical Center have produced results comparable with those obtained by Xeromammography, but with absored dosage reduced to approximately 20% of the latter.

4. Automated control systems

There are many sophisticated X-ray generating units and control systems which compute the optimum settings for the desired X-ray procedure and automatically control operating parameters to obtain standardized results with the lowest possible exposures of the subject. Although the X-ray generator and image forming equipment may be conventional, advances lie in the ability of the systems to optimize and standardize results. One supplier offers preprogrammed control applicable to over 200 procedures. Among the variables coordinated in these programs are tube voltage, current, exposure time, beam collimation, picture size, filtering and positioning. Different values of these parameters may be required for each of several hundred procedures a large general hospital may encounter.

Reduction in exposure derives from avoidance of repeated exposures due to errors or the failure to optimize settings.

5. Computer aided tomography

Tomography is the term adopted in the medical profession for X-ray radiography in which details within the interior of the subject are not shadowed or blocked from view by more dense body material in the path of the X-ray beam. While such shadowing poses little problems in X-ray analysis of a bone fracture, it reduces substantially the diagnostic value of X-rays for evidence of lesions or disease within many body organs, most particularly the brain.

In computer tomography the subject is scanned by a narrow X-ray beam which is rotated 360° around the subject in the plane being examined.

During this rotation several hundred X-ray pulses are passed through the subject from all angles in the 360° scan. The data generated by each of these pulses is fed to the computer, which constructs an image of the section of the body or body organ in the plane of the scan. This image can be projected as a visual display on a CRT or printed on hard copy. It can also be analyzed in a set of digital matrices printed out by the computer, each providing a two dimensional display of the X-ray absorption characteristics of the subject in the scanned plane.

Although computer tomography is not primarily intended as a substitute for conventional procedures to achieve dosage reduction, it offers X-ray diagnosis that would otherwise be possible only with exorbitant levels of exposure that could be more damaging than the disease.

D. ADOPTION OF ADVANCED EQUIPMENT

No survey has been conducted to evaluate quantitatively the extent of adoption of advanced equipment discussed above. To the extent that such conversion is not proceeding with "deliberate speed" the public is being exposed to heavier X-ray dosages than necessary or being deprived of desirable diagnostic procedures.

Factors retarding the adoption of advanced equipment:

1. Economic

The simplest improvement might be more widespread adoption of rare earth intensifying screens to replace tungstate screens. However, this step requires expenditure of about $175 for one pair of rare earth screens in lieu of $75 for one pair of tungstate screens in the size most commonly used (14" x 17"). There are many tens of thousands of cassettes in hospital use equipped with intensifying screens.

At the other extreme, installation of a computer aided tomography system complete with sophisticated ancillary equipment costs about $1 million.

With hospital administrations under increasing pressure to reduce operating costs, and most existing X-ray equipment relatively durable, it is difficult to invest in new equipment most desirable in terms of dosage minimization.

2. Performance

In some applications it is easy to judge the superiority of one system over another; in other applications such judgment may require very specialized understanding of technical subtleties not apparent to the radiologist. This will discourage or dissuade him from seeking such new equipment.

In some cases new equipment capabilities can be matched by more skillful and diligent utilization of old equipment well within the capability of the radiologist. His opting for that approach may not reflect the more limited capability or attitude of the technologist who routinely operates the equipment, nor the impact of a very high turnover rate of such technologists (as often as every 1½ years).

3. Reliability

New equipment featuring design innovations will often bring with it problems of reliability involving out of service time so that a critically needed procedure may not be available when needed. In a hospital with multiple facilities and equipment this may not be an important deterrent—in others it will.

4. Introduction and learning problems

Radiology is a technically complex subject and still quite controversial. Consequently, introduction of advanced equipment may require a substantial effort by the radiologist to develop new techniques and procedures, to assure upgrading of technologists in the application of those procedures, to implement safety standards, to absorb the penalties of reduced productivity during the learning period, etc. These considerations added to others can discourage adoption of new equipment technology.

E. POSSIBLE GOVERNMENT ISSUES INVOLVED

1. An assessment should be made of the degree to which hospitals, clinics, and private medical offices are adopting new equipment which meets diagnostic functional requirements with *minimum* dosage absorbed by the subject. A quantiative evaluation may require establishment of performance criteria. A well executed

qualitative assessment can support judgments about policy options. It appears that the BRH is best positioned for such a study, perhaps aided by other sections of HEW.

2. If the situation depicted in such an assessment appears unacceptable to HEW (or to the congressional committees with oversight responsibilities) a more extensive study should be performed, which includes a broadly based cost/benefit analysis of nationwide conversion to minimum dosage technology within several alternative timeframes.

3. Based on the findings of such a study, HEW should thereafter recommend legislation to the Congress to authorize such action if it deems prudent and necessary.

4. Independent of this, the relevant Committees of the Congress, including the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation should review such study reports with a view to developing appropriate legislation for advancing the health and safety of the public by improving the medical utilization of diagnostic X-ray technology.

B.—BACKGROUND PAPER ON UNNECESSARY X-RAY EXAMINATIONS

(Prepared by the Staff of the Bureau of Radiological Health June 1978)

The BRH estimate that 30 percent of all medical and dental x-ray procedures performed in the U.S. today may be unnecessary is derived from a review of the literature. This estimate is derived from a limited number of studies, some conducted at individual facilities. Unnecessary x-ray examinations (i.e., those which have no effect on patient care) occur for a variety of reasons including:

(a) inappropriate indications (7).
(b) inadequate patient history (5, 6, 7).
(c) repeat films caused by operator error or poor quality assurance practices (2, 8).
(d) medicolegal purposes (i.e., defensive medicine) (6, 9, 18, 19).
(e) financial benefit (7).

SOURCES OF UNNECESSARY X-RAY EXAMINATIONS

Based upon articles from the medical literature, we have attempted to quantify the problem of unnecessary x-ray examinations. Since only limited data on which to make projections is available, these estimates should not be regarded as being either exhaustive or statistically based. They are, however, suggestive of a problem which should be addressed.

Data for five types of specific x-ray procedures were used in developing the estimate of unnecessary procedures. In addition, an estimate for the remaining proportion of medical x-ray examinations which are unnecessary was applied. All estimates are in 1970 examination frequency numbers and have not been extrapolated to 1978.

As noted above, we define as unnecessary those x-ray examinations which have no effect on patient care. The actual number of unnecessary examinations may be higher or lower than our estimate. In addition, the actual number of unnecessary procedures that may be eliminated will depend on many factors including whether or not agreement on high yield patient selection criteria can be achieved, and whether or not the medicolegal (defensive medicine) atmosphere changes.

The greatest potential for saving may be in reducing the number of routine screening examinations. Since these examinations are performed on persons who are without known specific signs or symptoms, they should be analyzed for cost-effectiveness in finding disease. Screening examinations with unacceptably high costs per treatable disease found should be discontinued.

CHEST RADIOGRAPHY

Hospital screening

In an analysis of over 10,000 hospital chest x-ray examinations performed in a St. Louis hospital, Sagel et al. (15) found that 6,000 examinations were taken for routine screening purposes. Only 4 percent of these routine screening examinations provided new diagnostic information. The author concluded that chest screening radiographs were not warranted in patients under 20, and that the lateral projection would be eliminated for patients 20 to 39 years of age.

In a study of 1,393 preoperative chest x-ray examinations, Janower (11) found that only 2 cases (0.1 percent) had surgery postponed as a result of the radiographic findings.

In the Sagel study, the diagnostic yield was 7 percent or less for 55 percent of the routine chest screening examinations. This was prior to excluding patients with misleading histories and patients in whom the radiograph simply documented historical or physical findings. A four fold reduction in overall yield occurred when this correction was applied. We believe that improved selection criteria in lieu of standing operating procedures could avert many of the low yield studies. In view of the foregoing, we estimate that 50 percent of routine hospital chest screening examinations may be unnecessary.

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Other chest x-ray screening

The yield is assumed to be no greater than hospital screening. The actual yield is probably lower since the screened population is likely to have a smaller incidence of disease. Therefore, we also estimate that 50 percent of these examinations may be unnecessary also.

Estimate of unnecessary chest x-ray screening exams

Total hospital chest x-ray examinations—32×10^6 (20).

Percent assumed to be routine hospital screening 60 percent (15).

Percent of routine hospital chest x-ray screening examinations assumed to be unnecessary—50 percent (BRH estimate).

Possible unnecessary hospital chest x-ray screening examinations $(32\times10^6)\times(.6)\times(.50)=10\times10^6$.

Number of chest photofluorographic screening examinations—9×10^6 (20).

Percent assumed to be unnecessary—50 percent (BRH estimate).

Estimated number of unnecessary chest photofluorographic screening examinations—$9\times10^6\times(.5)=5\times10^6$.

Assumed number of routine occupational chest x-ray examinations—8×10^5 ('73 NCHS—National Ambulatory Medical Care Survey).

Percent assumed to be unnecessary—50 percent (BRH estimate).

Estimated number of unnecessary routine occupational chest x-ray examinations—$8\times10^5\times(.5)=4\times10^5$.

Estimated total unnecessary routine chest screening x-ray examinations—15×10^6.

SKULL RADIOGRAPHY

For evaluation of trauma

Phillips has shown a 40 percent reduction and further estimated that up to 70 percent of skull x-ray examinations may be unnecessary in emergency room skull radiography by using selected high-yield criteria (12).

Total hospital skull radiographs—3.6×10^6 (20).

Estimated percent related to trauma—30 percent (1).

Estimated percent of trauma examinations that are unnecessary—70 percent (12).

Estimated number of unnecessary skull trauma x-ray examinations $(3.6\times10^6)\times(.3)\times(.7)=0.8\times10^6$.

BARIUM ENEMA

In a study of 16,594 barium enema examinations performed in Manitoba Province, MacEwan (10) suggested that at least 25 percent of pediatric and 30 percent of adult barium enema examinations are unnecessary.

Estimated number of unnecessary barium enema examinations

Total number of barium enema examinations—3.4×10^6 (20).

Estimated percent that are unnecessary—25 percent (10).

Estimated number of unnecessary barium enema examinations—0.8×10^6.

ALL HOSPITAL X-RAY EXAMINATIONS (EXCLUDING ROUTINE CHEST, SKULL FOR TRAUMA, AND BARIUM ENEMA)

In a study of 619 separate radiological examinations at the University of Kentucky Medical Center, Rosenbaum (14) showed that 11.8 percent were adjudged to be unjustified for medical reasons. The figures cited did not include any examinations performed for legal documentation.

Estimated number of unnecessary hospital x-ray examinations

Number of hospital x-ray examinations excluding routine chest, skull for trauma, and barium enema—59×10^6 (20).

Percent assumed unnecessary—12 percent (14).

Estimated number of other unnecessary hospital radiographs—7×10^6.

One reason often cited for unnecessary examinations is the practice of defensive medicine. A large range of values exists for the percentage of all x-ray examinations which are done primarily for defensive purposes, 6–40 percent (6, 9, 18, 19). These examinations would constitute some fraction of the total unnecessary x-ray examinations and, therefore, are not shown separately. Also, studies have shown that up to 13 percent of examinations may be repeated because of operator error or poor quality assurance techniques (2, 8, 21). If this figure is applied to the necessary x-ray examinations only, then approximately 11 percent of

those examinations will be repeated because of poor quality. It should also be emphasized that, in this analysis, CT procedures, IVP's, UGI's, dental x-rays, and other common x-ray examinations were not considered.

SUMMARY OF ESTIMATED UNNECESSARY X-RAY EXAMINATIONS

Hospital chest screening exams	10.0×10^6
Nonhospital chest screening exams	5.0×10^6
Occupational chest screening exams	$.4\times10^6$
Emergency room skull X-ray exams	$.8\times10^6$
Barium enema examinations	$.8\times10^6$
Other hospital X-ray examinations	7.0×10^6
Total unnecessary X-ray examinations	24.0×10^6
Total medical X-ray exams (1970)	129.0×10^6
Percent unnecessary	19

Avoidable unnecessary X-ray examinations

Source:	*Percent of all medical X-ray exams*
Medically unnecessary [1]	19
Repeat (not included above)	11
Total	30

[1] Defined as including examinations done because of: (a) inappropriate indications; (b) inadequate patient history; (c) insufficient time between repeat examinations; (d) administrative errors; (e) medicolegal (defensive medicine) reasons.

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C.—THE ROLE OF PROFESSIONAL STANDARDS REVIEW ORGANIZATIONS AND PROFESSIONAL SOCIETIES IN REDUCING UNNECESSARY DIAGNOSTIC X-RAYS

I. STATEMENT OF PROBLEM

In 1977 the Bureau of Radiological Health (BRH) in the Department of Health, Education, and Welfare estimated that 160 million individuals would receive a total of 270 million diagnostic x-ray exams. BRH further predicted that one-third of those exams would be unwarranted, or would not contribute to the diagnosis and treatment of the patient (Villforth testimony, June 1977 hearings, Committee on Commerce, Science, and Transportation).

There are several reasons for the imprudent application of diagnostic x-rays:

1. Patients expect a doctor to use every means available to assure the most accurate diagnosis and treatment. The hazards associated with the use of x-rays are overshadowed by the belief that they are an integral part of effective patient care.

2. The system of prospective reimbursement which underlies Medicare and Medicaid incorporates no incentive for restraint in the administration of x-rays and other ancillary services.

3. The present defensive climate in which physicians must practice encourages the excessive use of x-rays to avoid malpractice suits. The president of Blue Cross/Blue Shield, Thomas C. Paton, estimated that as many as 40 percent of x-rays administered are for medico-legal purposes (Medical World News, January 12, 1976). In a survey conducted by the American Academy of Pediatrics, members were asked how liability problems affected their practice. Half said they were ordering more x-rays (Medical World News, January 12, 1976).

4. The difficulties are great in changing a health care practice whose benefits are immediate and proven. For example, although performing chest x-rays as a mass screening technique has been discouraged by BRH and professional societies since 1972, this practice still persists in some schools, businesses and hospitals.

5. The user (physician, technologist, radiologist) may be guilty of poor x-ray practices. BRH estimates that 10 percent of all diagnostic x-ray exams must be repeated, and that 75 percent of these repeats are avoidable through improved practices in x-ray facilities (FDA Consumer, December 1977/January 1978).

II. CURRENT PROGRAMS AND ACCOMPLISHMENTS

A. The Bureau of Radiological Health

BRH is approaching the problem from several directions. The June 1977 hearings (pp. 49–50) contain a description of these programs and their objectives:

1. Assessing the nature and magnitude of the problem by estimating the radiation dose received from various specific examinations, and by ascertaining medical radiation trends;

2. Developing and promoting voluntary medical recommendations;

3. Developing and promoting the use of x-ray quality assurance measures;

4. Reaching radiation users by upgrading the teaching of radiation protection in professional and technical schools, and conducting continuing education for practitioners;

5. Educating consumers of radiation services;

6. Helping to establish standards for users, generally implemented through other agencies; and

7. Strengthening the ability of state and municipal control agencies to improve user practices on a local level.

B. X-ray records

Several approaches are under consideration. For example a system might be established whereby a lifetime radiation history is maintained for each person as part of one's medical record either by the individual, the physician or in a central data bank. Health maintenance organizations lend themselves to this approach where x-ray files can be centralized and analyzed for large numbers of patients.

Cards are presently available from BRH which allow the individual to record and carry with him a complete record of past x-rays. This information would be incorporated into the physician's decision about additional x-rays.

Establishing a computer-based national medical information system for x-ray histories on each individual has also been suggested. The physician or radiologist could tap into the system to learn the x-ray history of the patient. The centralized, comprehensive nature of this system would also support statistical analyses regarding current x-ray practices. Many persons have doubts about the desirability and the economic feasibility of this approach, citing the potential infringement upon the privacy of doctor and patient and the high cost of maintaining such a national system. (Dr. Barbara McNeil, Peter Bent Brigham Hospital; Elijiah White, National Center for Health Statistics; Mary Tierny, PSRO) The Office of Technology Assessment, however, recently issued a statement (May 9, 1978) proclaiming the need for a coordinated federal effort to explore the utility of such health care information systems.

C. Professional standards review organizations

Professional Standards Review Organizations (PSRO) established under Public Law 92–603 (the 1972 Amendments to the Social Security Act) provide a useful means by which to improve user practice. Housed within the Health Care Finance Administration, the PSRO is a national network of physicians, who, through local peer review, assess the quality of medical care and ensure that both health care resources and facilities are appropriately used. As of 1977, there were 203 designated PSRO areas in the United States.

PSROs have initiated a program to reduce the number of ancillary services performed (all non-line items on the hospital bill) including x-rays. BRH has estimated that the annual health care cost of unnecessary x-rays is $2 billion. This PSRO program is being conducted in three stages:

1. Data are gathered after discharge of patient on several aspects of patient care (Profile Analysis).
2. From the Profile Analysis, criteria to determine the appropriateness of x-rays and other ancillary services are developed.
3. Based on these criteria, through concurrent review, the PSROs can monitor and standardize x-ray practices by physician, hospital, by symptoms/diagnosis, thus reducing the number of unnecessary x-rays.

Although most PSRO projects are concerned with ancillary services generally, some deal specifically with reducing unnecessary x-rays. Two PSROs in Massachusetts are studying the positive signs and symptoms which can be correlated with a positive CAT scan. Three physicians have donated their time for the study, which utilizes PSRO-supported research assistants and computer time. In another effort, PSRO coordinators plan to distribute information resulting from a BRH/University of California at San Francisco study to develop criteria for the appropriateness of chest films, pelvimetries and voiding cystourethrograms in children.

The PSRO system also provides a means to conduct clinical evaluations of criteria for determining when x-rays are needed. Thus, a study by the University of Washington found that administering skull x-rays in the emergency room after trauma to the head did not contribute to patient diagnosis or treatment (Bell and Loop, 1971). In an interagency agreement between the BRH and the Health Care Finance Administration, Washington State PSROs have been contracted to test nine high yield criteria for skull radiography in the emergency room. The ordering of these films has been cut by 30–40 percent at savings of millions of dollars yearly. Other PSROs are being encouraged to do follow-up studies on patients to determine the ultimate efficacy of the program. PSROs are also vocally opposed to Medicare coverage of body scans until efficacy studies demonstrate they are more effective than other methods, such as ultrasound and conventional x-rays.

D. Professional associations

There are several professional associations, societies, academies, etc., which participate in quality assurance and radiation protection programs with BRH and PSROs (collectively and individually), and with private business. They include:

American Academy of Dermatology.
American Academy of Orthopedic Surgeons.
American Academy of Pediatricians.
American Association of Physicists in Medicine.
American College of Obstetricians and Gynecologists.

American College of Chest Physicians.
American College of Radiology.
American Dental Association.
American Industrial Hygiene Association.
American Insurance Association.
American Medical Association.
American Nuclear Society.
American Occupational Medical Association.
American Osteopathic Association.
American Podiatry Association.
American Public Health Association.
American Radium Society.
American Roentgen Ray Society.
American Society of Radiologic Technologists.
American Veterinary Medical Association.
Association of University Radiologists.
College of American Pathologists.
Genetics Society of America.
Health Physics Society.
Industrial Medical Association.
Radiation Research Society.
National Electrical Manufacturers Association.
Radiological Society of North America.
Society of Nuclear Medicine.

Most programs consist of three elements:

1. establishing and promoting voluntary recommendations and standards regarding x-ray practice;

2. educating radiation users through correspondence courses, curricula designed for technical and professional schools, and continuing education courses (often at the annual convention of the organization);

3. disseminating published materials (i.e., journal articles, pamphlets, statements of policy, user guidebooks, etc.) designed to acquaint the physician, radiologist or technician with the most current information on x-ray use, such as number of shots, optimum view, length and magnitude of exposure, and what criteria justify the ordering of an x-ray.

Almost all of these organizations are associated with the American College of Radiology, the National Council on Radiation Protection and Measurements, or the American Society of Radiologic Technologists. These three organizations act with BRH as the major coordinators of radiation protection activities.

D.1. The American College of Radiology

The American College of Radiology (ACR) is an Association of approximately 14,000 physicians and physicists who are board-certified radiologists. Membership is contingent upon attaining 150 hours of continuing medical education courses.

The ACR's major effort to reduce unnecessary x-rays is a study which will "establish a credible foundation upon which the development of standards (for diagnostic radiology) may be built." (Applied Radiology, May–June 1977) The study is funded by a Federal grant from the Health Services and Mental Health Administration of HEW, awarded in 1972. The project began in 1974, and is expected to last 10 years. The efficacy study, as it is called, is divided into three phases. Phase one, which is nearing completion, "estimated the effect of emergency room x-ray exams on diagnostic thinking." Phase two will evaluate the role of different modalities of x-ray treatment. Phase three will attempt to evaluate the ultimate benefit of a radiologic examination to the patient. The results of these studies will be used to develop a handbook or set of tables/charts for physicians to consult before an x-ray is ordered. However, Dr. Russell H. Morgan of ACR testified at the June 1977 hearings that Federal support for the study has dwindled "to a level which prejudices completion of the field portions of the study." (June 1977 hearings, page 245) Findings from the study are currently disseminated via the ACR monthly bulletins and through scientific journals and the popular press.

At this early stage, ACR committee members are aware that their efforts have stimulated local efficacy projects, medical staff discussions and certain changes in patterns of x-ray practice. The results of the study should eventually have an impact upon the deliberations of the PSROs and the compensation profiles of various health insurance carriers.

The ACR devotes about $3 million of its $6 million budget to education programs. In addition to continuing education, self-evaluation courses, fellowship programs, weekend seminars, practice films and slides, ACR also sponsors, with BRH, the development of a "learning lab file" at the University of California at San Francisco for x-ray films which illustrate diagnostic x-ray indicators. Similar learning lab files could, of course, be established at other universities.

The ACR has worked with the American Academy of Pediatricians to discourage the use of fluoroscopes. It has worked with the American College of Chest Physicians, the Center for Disease Control and BRH to halt community chest x-ray surveys as a screening technique. A policy statement on these techniques was issued in 1972. In 1976, the ACR worked with the American College of Obstetricians and Gynecologists, NCPR and BRH on statements of good practice in abdominal x-ray examinations of pregnant women. In 1974, under a program developed with BRH, it distributed sample gonad shields to all its members for use in abdominal examination of males. At the June 20, 1977 Conference of State Radiation Program Directors, the College cosponsored discussions on current problems with mammography, CT scanners and other current radiation issues. In 1971, the College in conjuncion with BRH developed a publication and film entitled, "X-ray Examinations: A Guide to Good Practice," which reached one-half million health practitioners. Under contract with NIOSH, ACR joined the American Academy of Orthopedic Surgeons, the American Occupational Health Association, the Industrial Medical Association, and the Health Services and Mental Health Administration, in a project to study the use of lumbar spinal x-rays in preemployment physical examinations. A symposium was held in January of 1973 on this subject. When ACR undertook training programs to assist physicians with chest x-ray examination requirements for coal miners under the Black Lung Act around 1975–76, it collaborated with the AMA, the American College of Chest Physicians, the American Occupational Health Association, the American Osteopathic Association and the American Society of Radiologic Technologists.

D.2. The National Council for Radiation Protection and Measurements

The National Council for Radiation Protection and Measurements (NCRPM) is a nonprofit corporation chartered by Congress in 1964 (P.L. 88–376). The Council is composed of 75 members elected to 6-year terms. Three hundred additional scientists are chosen to work on 60 committees that analyze and recommend solutions to specific problems relating to radiation protection and measurement. After several levels of review and approval, health professionals are notified via news release of the availability of reports. More than 50 reports have been issued; several of them bear upon good x-ray practice:

Report No. 33 Medical X-ray and Gamma-ray Protection for Energies up to 10 MeV

Report No. 35 Dental X-ray Protection

Report No. 39 and 43 Radiation Protection Criteria (NCRP philosophy)

Report No. 48 Radiation Protection for Medical and Allied Health Personnel

Report No. 54 Medical Radiation Exposure of Pregnant and Potentially Pregnant Women (to be published)

The network of scientists from universities, laboratories, state governments, and industry groups working on these committees provides a convenient means for transmitting information to users in the different settings of radiation technology practice.

NCRPM describes its relationship with 30 organizations from the private and governmental sectors as collaborative, providing for exchange of ideas. In some cases, substantive contributions are derived from these sources. The NCRPM also acts as a clearinghouse for information on radiation protection to radiation users and consumers, and also offers educational programs.

D.3. The American Society of Radiologic Technologists

The American Society of Radiologic Technologists (ASRT) works to assure that technologists are well trained. There are an estimated 130,000 to 150,000 operators of radiologic equipment in this country. Half of these, through course work and examination, have met the educational standards prescribed by the profession. Technologists certified by the Registry of Radiologists must study a minimum of 2 years in programs approved by the AMA. The ASRT has developed a curriculum used at accredited schools of radiologic technology. There is presently no requirement for continuing education, but programs are regularly offered by ASRT, and articles are published in scientific journals. Annual meetings of ASRT offer quality assurance and radiation protection courses.

III. SUMMARY

The most promising approach to reducing unnecessary x-rays, and the one most frequently followed by professional organizations, is first to analyze the need for an examination and then to establish guidelines or criteria for more cautious administration. This is the objective of the ACR, PSRO and BRH projects. The results of the efficacy studies on chest exams and mammograms (in women under 50) as mass screening techniques, or of skull films in the emergency room after trauma to the head, have indicated the possibility of significant reductions in patient exposure without negative diagnostic effects. More studies need to be conducted on x-ray categories for which the cost/benefit to the patient can be evaluated with greater accuracy. (For pelvimetries, for example, it should be relatively easy to establish criteria; upper GI series or IVP (kidney) studies may be more difficult.)

At the same time, it is necessary for continued clinical evaluation of the guidelines and criteria, such as the study conducted by the University of California at San Francisco and the PSRO (see page 92). It is equally important to encourage the application of these findings to x-ray usage.

The statistics concerning the actual incorporation of new practices are rough at best. For example, the American Hospital Association was unable to say how many hospitals still require routine chest films for admittance. Also, there have been no surveys conducted on the extent of gonad shielding since 1970 when a BRH study disclosed that 90% of the x-rays in the U.S. are taken without this precaution. (New Times, 3/4/77)

Criteria to determine whether or not to order an x-ray may also be useful to the physician in avoiding malpractice suits. If a doctor can assure the court and the plaintiff that, based upon criteria established by his profession, the x-ray he did not administer would not have contributed to the welfare of the patient, a stronger defensive posture could be achieved. Still, the effect of the present malpractice climate upon x-ray practice merits more study. It would be useful to compare patterns in the administration of x-rays in a hospital or health maintenance organization (HMO) where physicians are salaried and not personally liable to malpractice suits, with those of private practitioners.

As discussed in the findings of this report and in the record of the June 1977 hearings, there is also a need to upgrade the qualifications of the estimated 50% radiologic technicians who do not meet professional standards.

D.—MICROWAVE DETECTORS

I. PURPOSE

This review of microwave detectors was initiated to provide the Committee with information regarding the price and operating characteristics of instruments and services currently available for possible consumer use and protection against excessive exposure to microwave irradiation from commonly used systems and appliances, especially microwave ovens. It also highlights some of the impediments to more ready availability of such instruments and services.

II. SUMMARY

Several types of microwaves radiation power density detectors are currently being manufactured, but no reliable instrument suitable as a personal hazard detector has yet been developed. Only one experimental cumulative dosimeter has been constructed. Most of the instruments currently on the market are outside the price range of average consumers; however, the technology to build inexpensive microwave leakage detectors does exist. Production and marketing of these devices are not proceeding because:

1. the devices either do not meet current HEW standards or they have not undergone sufficient testing to determine whether they qualify;
2. microwave oven leakage testing in the home by appliance service establishments is available in metropolitan areas for about $20, thus moderating the need for further development of a home device; and
3. potential manufacturers fear law suits that might arise from inadequate product performance.

Other factors also contribute to industry disinterest. For example, no market study could be found relating to the demand for such an instrument or the potential profits from manufacturing it. The engineering, labor and overhead expenses involved with low volume production may be too high to allow both an acceptable profit and an acceptable consumer price.

Several issues relating to such instrumentation were developed during this review.

1. Careless or improper use of home microwave detectors could lead to mass nuisance calls to repairmen and cause unnecessary concern over oven safety.
2. Lack of credible information on the accuracy and potential reliability of inexpensive instruments makes it impossible to determine their ultimate utility.
3. A leading manufacturer of microwave ovens recommended emphasis on investigation of the biological effects of those radio frequencies (RF) which are nearer the human resonant frequency. Exposure to this radiation is more prevelant than to microwaves. In this connection it should be noted that instrumentation of the type reviewed here could be made applicable to most RF frequencies.

III. FUNCTIONAL DESIGN REQUIREMENTS

A. Frequency range

Microwaves are used for a variety of purposes including among others:

Medical diathermy;

Drying wood pulp for use in the paper industry;

Cooking and food processing—consumer ovens with 650 watts of power; industrial and restaurant ovens at 2,000 watts, conveyor belt ovens at 10,000 watts;

Military and commercial navigation;

Defense systems;

Communication system.

Some type of microwave detector is needed in each of these applications either to test the equipment or to protect personnel involved in the production, servic-

ing or operation of the equipment. The frequency ranges of these devices vary from oven testers at .915 and 2.45 GHz [1] to elaborate broadband sensors with ranges from .01 to 3.0 GHz and 3.0 to 18.0 GHz. The absence of equipment to sense frequencies higher than 18 GHz is due to the lack of calibration standards. Instruments with broadband capability are more expensive than single frequency devices. To detect radiation leaks from microwave ovens, a detector must be sensitive to 2.45 GHz and .915 GHz. The use of .915 GHz in ovens has been discontinued, so the need for detection at this frequency is diminishing.

B. Reaction time

Federal regulation requires that all microwave oven test devices come to 90 percent of their steady state reading within three seconds.[2] All the devices investigated were reported to meet or exceed this requirement. Some instruments allow the operator to select between two response times, one about three seconds and the other about one second. The advantage of two response times is that the slow setting yields an average power density measurement and the fast setting allows the peak power densities to be monitored in ovens employing a stirrer. The devices are accurate only for continuous source and relatively slow multi-second pulsed source applications. For radar and other sources with a high pulse rate, they read only average power density. In the case of very short radar pulses, some instruments may in fact show no reading at all, even though the radiation intensity still exists.

C. Accuracy

According to manufacturers, every leakage monitor commercially available meets the stringent HEW accuracy standard of 1 dB. The Bureau of Radiological Health is planning to relax this standard to 2 dB or to allow oven manufacturers further flexibility provided all instrument errors are documented in combination with a lowering of leakage rejection limits.

IV. AVAILABILITY OF TESTING SERVICES AND INSTRUMENTS FOR CONSUMER USE

A. Testing services

A sample survey of 32 of the approximately 200 establishments listed in the District of Columbia Yellow Pages under "Ranges and Stoves—Dealers and Services" disclosed that eleven of these serviced microwave ovens (34%) and 8 of these would send a serviceman to the home to do the test (25%). The price for this service ranged between $15 and $24 with the average charge about $19. Charges ranged from $0 to $17 for units brought into the service shops. It is expected that similar service for oven checking exists in every community large enough to have several appliance service establishments. Other possible sources for this service are State and local government health service agencies.

B. Available instruments

The prices of the detectors surveyed ranged from $25 to $20,000. The $10,000 to $20,000 devices are tunable field strength meters with which one can examine the field strength of any particular region of radio or microwave frequencies with great precision. The expense and fragility of this equipment limit it primarily for research with little application to microwave oven leakage.

The next category of instruments range in price from $1,075 to $225. This group is manufactured for use by microwave oven manufacturers and service establishments. All of these devices meet Bureau of Radiological Health standards. The price differential within this category is a result of different accessory features such as optional reaction times, increased range, specialized probes or sensors, etc.

Another category much closer to consumer price levels includes four products ranging from $25 to $75. Of these, one has been halted due to technical problems. Another does not meet BRH meter standards as it is a threshold detector that powers light emitting diodes (LEDs) at specific power density levels.

C. Current instrument developments

Some further developments are underway. For example, a company with interest in a liquid crystal detector, indicates that it is feasible to produce such

[1] One GHz is one billion cycles per second.
[2] HEW Publication (FDA) 76–8035, Regulations for the Administration and Enforcement of the Radiation Control for Health and Safety Act of 1968.

a device for retail at less than $5. Another company estimated that it could be done for under $10. Dr. Jeremy Landt of the Los Alamos Scientific Laboratory developed a simple diode rectified device whose parts cost in large quantities would be about $1. He stated that the sensitivity could be enhanced with more precise components increasing the parts cost to $3. Addition of a meter display increased estimated cost to $7. Apparently the technology for a consumer priced leakage detector exists.

However, the Electromagnetics Branch of the BRH pointed out difficulties with these devices. Not even the $200 models actually meet BRH standards under worst case conditions. The liquid crystal device is considered too unstable to be successful. None of the scientists have run extensive tests to determine the accuracy of their inventions.

Development of microwave dosimeters for measurement of accrued exposure may have been prevented by the widespread belief that the rate of exposure to nonionizing radiation is much more significant than accrued dosage. According to Dr. Arthur Guy at the University of Washington, low-level exposure over a long time may give the same dosage as high-level exposure for a short time but the physiological effects may be quite different.

D. Marketing issues

Some of the inventors and industry personnel identified potential legal problems as an impediment to commercial instrument development. There is reluctance among commercial manufacturers to accept ill-defined liability related to injuries alleged to have resulted from a faulty appliance whose poor performance was not detected by a faulty instrument.

Major appliance manufacturers discourage use of instrumentation which increases cost and may provide misleading information, or information of value only to technically oriented users. (The virtual disappearance of oil pressure and water temperature gauges as well as ammeters and voltmeters from automobiles is illustrative of this marketing practice.)

Primarily, however, the indistinct market demand and availability of service center testing at an affordable price seem to have reduced incentives for large-scale instrument development.

V. TECHNICAL FEATURES AND DESIGN BARRIERS

The technically discriminating feature among different types of microwave detectors lies in the probe or radiation sensing mechanism utilized. Various methods of amplification and data output are used but they are of little consequence in determining the principal usage of each detector type. For this reason the different types have been categorized by sensory component; the output mechanisms are only briefly discussed.

A. Antennas

Most microwave probes or sensors use one or more small mutually perpendicular dipoles to sense the electric field of the radiation. To obtain good determination of the power density at relatively low frequencies (below .5 GHz) both components[3] of the electromagnetic radiation must be measured. For the higher microwave frequencies included in the review it is usually sufficient to sense and measure only the electric component.

The number of dipoles involved in the sensing function is determined by the intended uses of the instrument. Its cost is generally proportional to this number. Three dipoles are used to sense electric field components in three-dimensional planes. Some extremely sensitive and expensive instruments used in research may have more than three dipoles to provide omnidirectional sensing. Microwave oven leakage testing does not require an omnidirectional sensor as the direction from which the radiation propagates is known. A two-dipole antenna positioned perpendicular to the surface under investigation provides adequate sensing.

B. Diode rectifiers

In one type of sensory mechanism a diode rectifier terminates each antenna. The diode rectifier consititutes a durable probe which can operate into the hundreds of watts per cm^2 region without burnout. It performs well for the broadband of frequencies between .1 and 10 GHz and is, therefore, useful at the microwave oven frequencies of .915 and 2.45 GHz. Diode behavior is, how-

[3] Microwaves are a form of electromagnetic radiation containing both an electric and magnetic component or field.

ever, strongly dependent on the ambient temperature which can introduce sensitivity variations as large as 2.5 percent/C°.

C. Bolometric devices

Bolometric devices are sensitive to the heating effect of microwave radiation. In some instruments this heating effect is applied to alter the electrical resistance of a carefully balanced electrical curcuit thus indicating the presence and intensity of the microwave radiation. These detectors also suffer from changes in ambient temperature which affect instrument sensitivity and also cause drift or instability of the instrument zero point.

In another gas pressure type of bolometric device, a thin resistive film enclosing a gas filled sphere is heated by the microwave radiation. The gas in turn is heated and the resulting pressure increase is translated into a microwave power density measurement. The effect of variations in ambient temperature are accounted for by incorporating a second uncoated gas sphere and effectively subtracting the unwanted effect of ambient temperature changes. Such gas pressure systems can be used to measure wide bandwidth radiation, but suffer from relatively low sensitivity.

A liquid crystal bolometric device also uses heat sensing principles. In 1970 work on liquid crystal power density meters was done by a leading instrument manufacturer who obtained a patent but did not pursue the development.[4] Another liquid crystal microwave detector invented by Drs. Glen Fanslow and D. T. Stephenson at Iowa State University has an unexplored potential for general public use. Basically, the device consists of two plastic disks—one to measure ambient or room temperature and another with a metallic coating to absorb the microwave energy. The second disk converts the absorbed microwave energy into thermal energy and the difference in temperature between the two disks controls the wavelength, that is, the color of light re-emitted by the liquid crystals. The determination of this color difference provides a quantitative measure of microwave power density present in the radiation.

The sensitivity of the simplest such device was 1°C temperature difference for 1 milliwatt/cm^2 of microwave radiation. Since the eye can detect color changes resulting from 1°C temperature differences, the device would be able to indicate microwave power density to the nearest milliwatt/cm^2. A more expensive version of the detector provides three times this sensitivity.

Advantages of this device are its simplicity, low cost (it was estimated to retail in the $5 to $10 range), and its nondependence on frequency. Its slow response time of 4 seconds to full scale is a disadvantage which limits the utility of the device to long-pulsed and continuous microwave sources. This detector is less accurate and more difficult to calibrate than other types. It also responds to ambient factors other than microwaves which can produce a temperature difference between the two disks.

D. Thermocouple devices

Another type of microwave detector utilizes thin film thermocouples to sense microwaves. The thermocouples need no antenna as portions of the films act as a microwave receiver. This sensor is virtually unaffected by changes in ambient temperature and encounters almost no output drift. Its construction accommodates devices with very broad bandwidths. Its principal shortcoming is its low burnout characteristic.

E. Dosimeters

Only one cumulative exposure measuring device was found to have been built. It was an experimental device constructed by a graduate student at Purdue University in 1973. It consisted of small diode-rectified dipole antennas which passed current, extracted from the microwave radiation, into a small electrolytic cell. The extent of the electroplating in the cell measured the total dosage accrued over a long interval. The amount of plating was determined by running a constant reverse current through the cell and recording the time necessary to deplate the cell electrode. Three companies expressed commercial interest in the device but did not pursue its development. The parts cost for this small "sugar-cube" sized device (1″ x ¾″ x 1″) was estimated to range from $2 to $4, depending on the desired sensitivity.

The table on the following pages summarizes the performance data obtained on a variety of instruments covered by this survey.

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[4] Bureau of Radiological Health Publication, No. 78, May 1970, Development of Liquid Crystal Microwave Power Density Meter.

Manufacturer: Instrument	Price	Response time(s) *	Frequency range (GHz)	Maximum power density range (mW/cm^2)	Continuous wave overload power (W/cm^2). †	Threshold warning	Weight (pounds)
Cicoil: Micro-gard	$34.95	NA‡	0.5 to 13	NA	NA	Yes	0.25.
General Microwave Corp.:							
Raham model 1	475	1	0.3 to 18	200	0.5	No	3.25.
Raham model 2	275	1	0.01 to 3	200	1	No	3.25.
Raham model 3	750	1	0.3 to 18	200	0.5	No	3.25.
Raham model 12	625	1	0.01 to 18	200	1, 0.5	No	3.25.
Holaday Industries:							
HI-1500-3	175	NA	2.45	NA	1.5	Yes	NA.
HI-1501	225	1, 2.5	2.45	100	1.5	No	NA.
HI-1600	269	1, 2.5	0.915, 2.45	20	1.5	No	NA.
HI-1700	800	1, 2.5	2.45	20	1.5	Yes	NA.
International Crystal: Microdek 310	75	NA	2.45	NA	NA	NA	0.4.
Instruments for Industry, Inc.:							
EFS-1 (RF only)	495	NA	$10.^{4}$ to 0.2	300 V/m **	NA	Option	1.
EFS-2 (RF only)		NA	$10.^{5}$ to 0.25	300 V/m	NA	Option	1.75.
EFS-3 (RF only)		$10.^{-6}$	$10.^{5}$ to 0.25	300 V/m	NA	Option	1.75.
NARDA Microwave Corp.:							
Model 8100B	1,075	0.5, 3. ††	0.915, 2.45	200	0.6, 0.04, 0.006	Yes	4.5.
Model 8201	370	1.2	2.45	100	0.3, 0.04	No	1.3.
Model 8250	225	1.2	2.45	100	0.3	No	1.3.
Model 8601	NA	1.2	0.3 to 26	100	0.3, 0.1	No	1.5.
Model 8602	NA	1.2	0.01 to 0.3	100	0.3, 0.1	No	1.5.
Model 8603	NA	1.2	0.01 to 26	100	0.3, 0.1	No	2.
Model 8606	NA	1.3	0.3 to 26	100	0.3, 0.006	Yes	5.8.
Model 8607	2,120	1.3	0.01 to 0.3	100	0.3, 0.006	Yes	5.8.
Model 8608	NA	1.3	0.01 to 26	100	0.3, 0.006	Yes	5.8.
Princeton Microwave & Testing Co.: Micromate	35.95	1	2.45	10	NA	No	0.75.
Radiation Sensors Inc.:							
Model 05-1-7	25	NA	2.45	7	0.04	Yes	NA.
Model 08-2-5C	NA	NA	2.45	5	0.04	Yes	NA.
Model dp-1-4-9	Leased	NA	2.45	9	0.04	Digital	NA.
Simpson Electric Co.: Model 380	246.75	1.2, 3	2.45	100	0.3	No	1.

* All response times are listed in seconds, note that 10^{-6} seconds is 1 microsecond.

† This is the maximum continuous wave power density to which the device may operate without sustaining damage. Peak power pulses 30 to 1,000 times the continuous wave rating may be tolerated depending on the instrument. Where multiple entries occur the detector uses 2 or more interchangeable probes.

‡ NA—Information not available at time of survey.

** V/m—Volts per meter.

†† With other probes the response times could also be 0.75, 3 or 1, 3.